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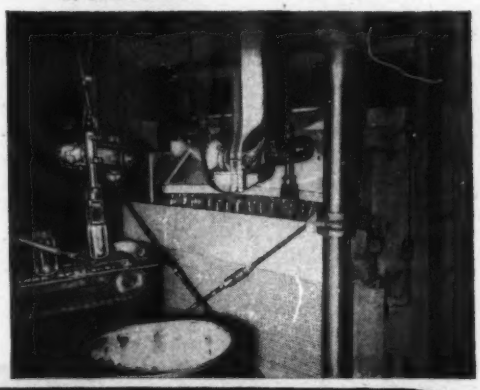

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the glass industry

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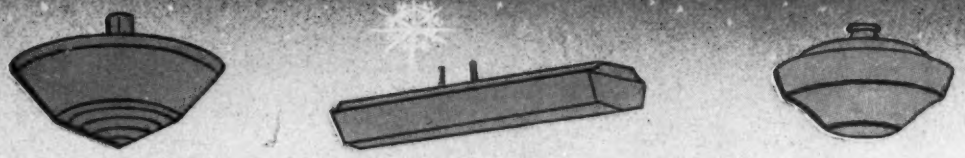

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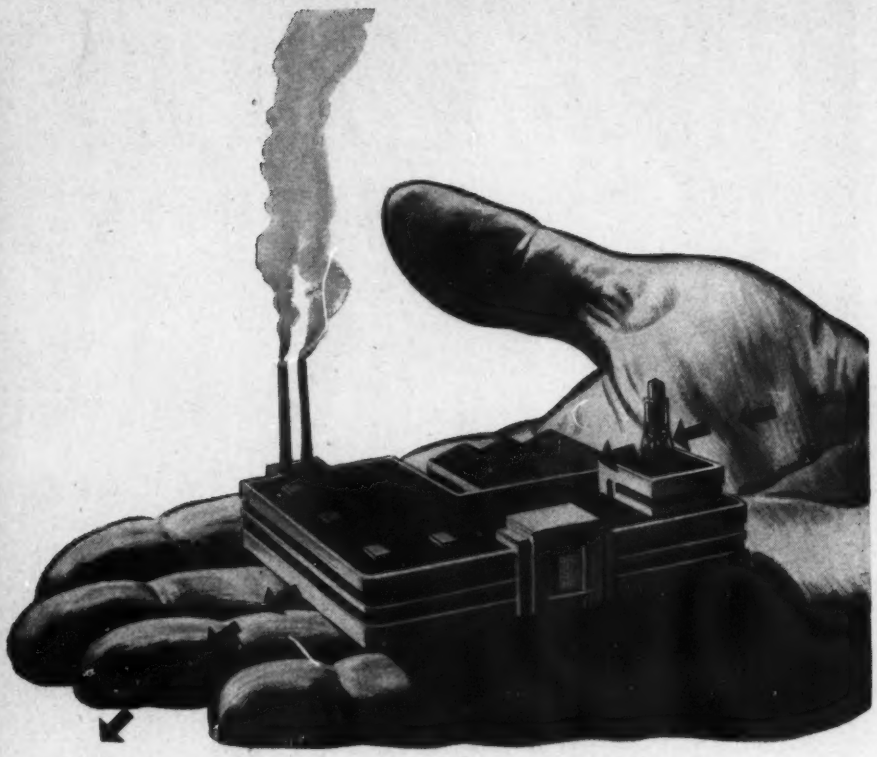

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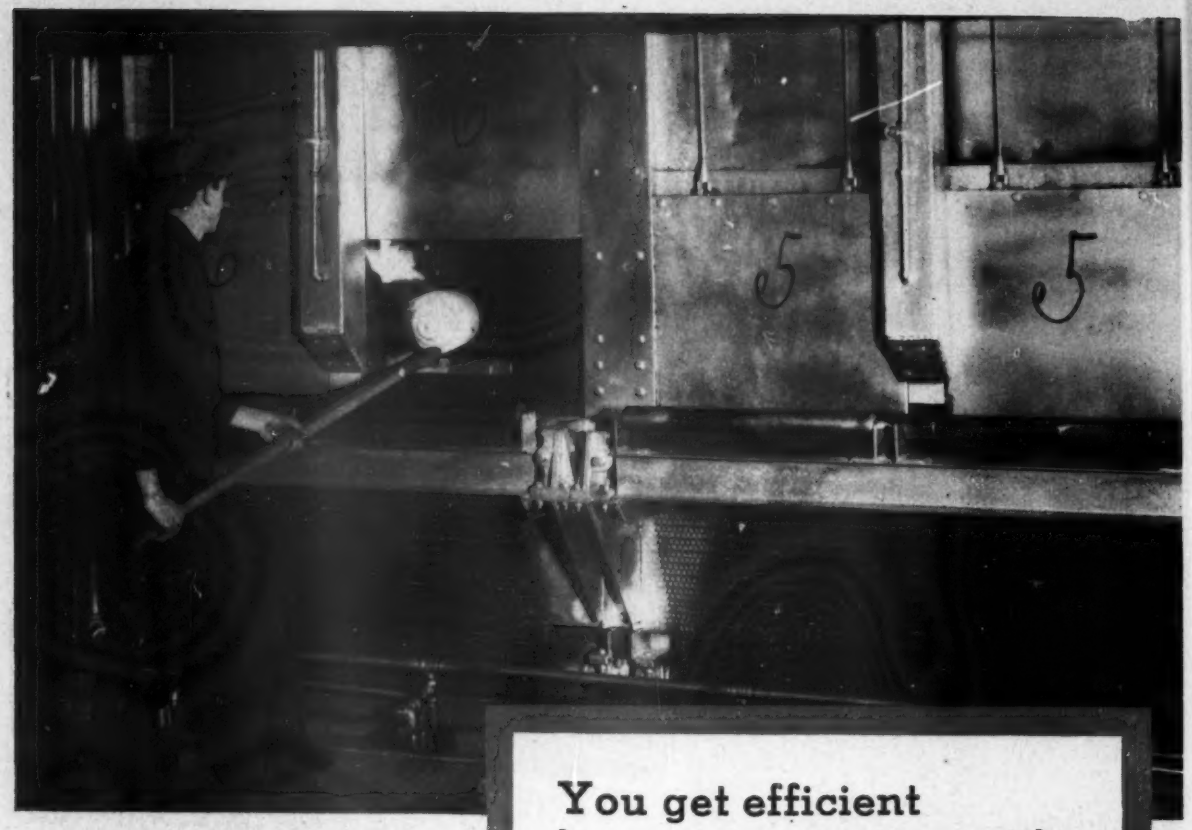

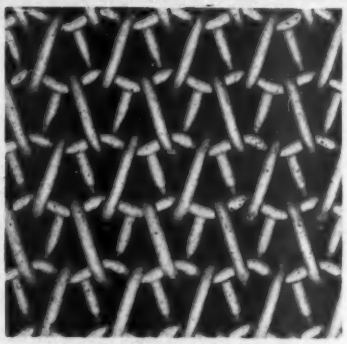

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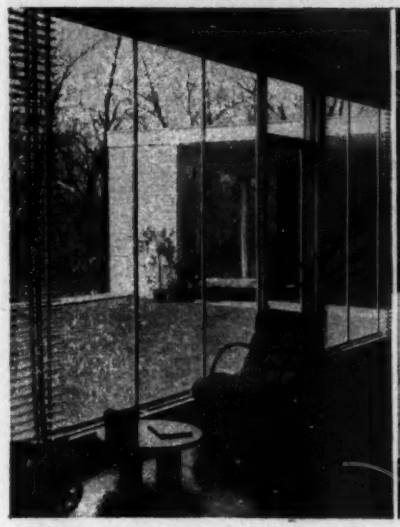

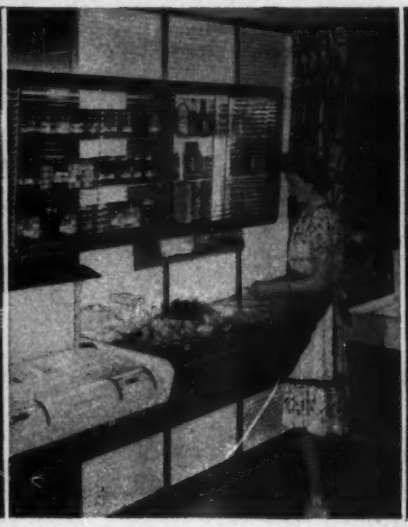

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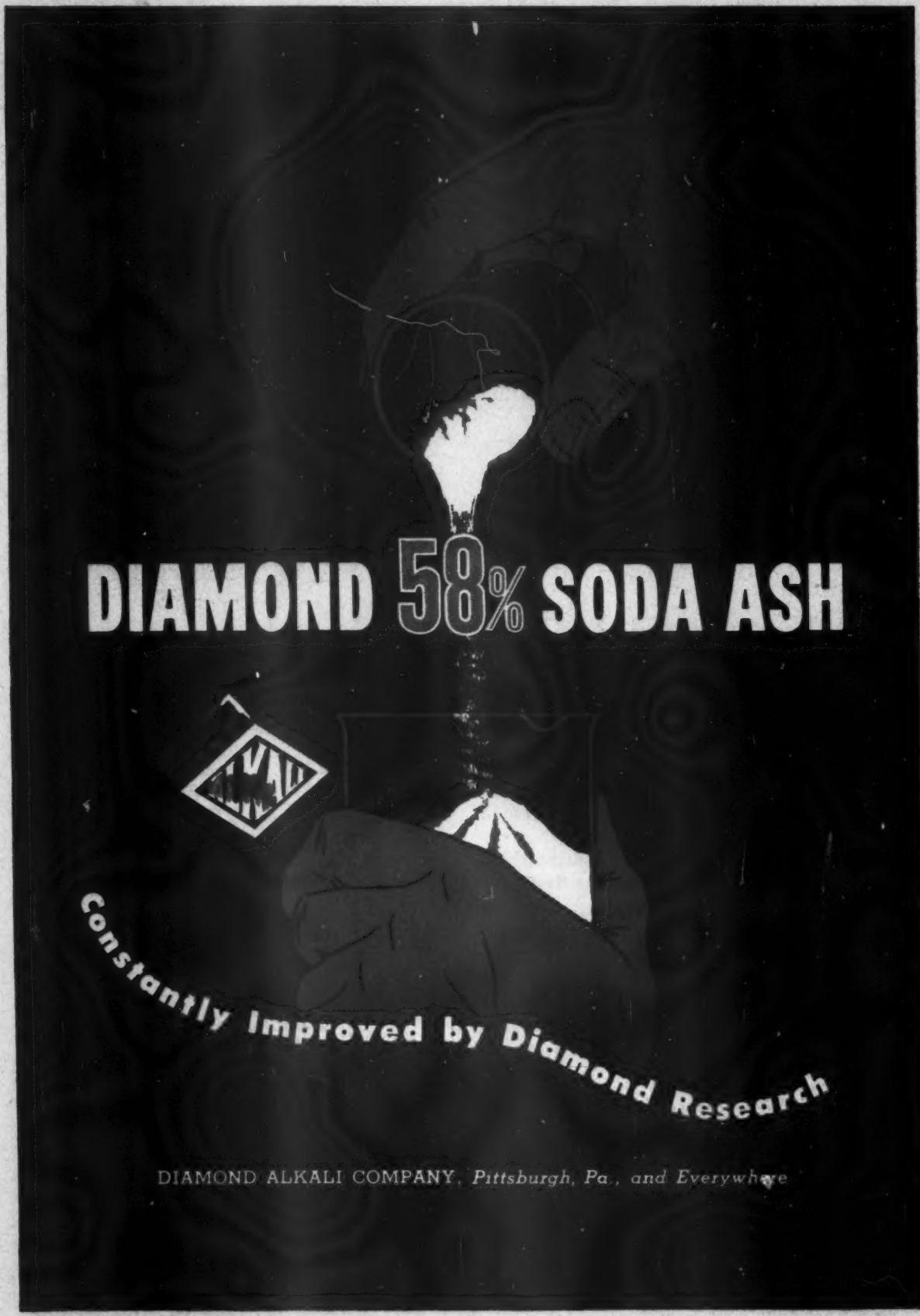
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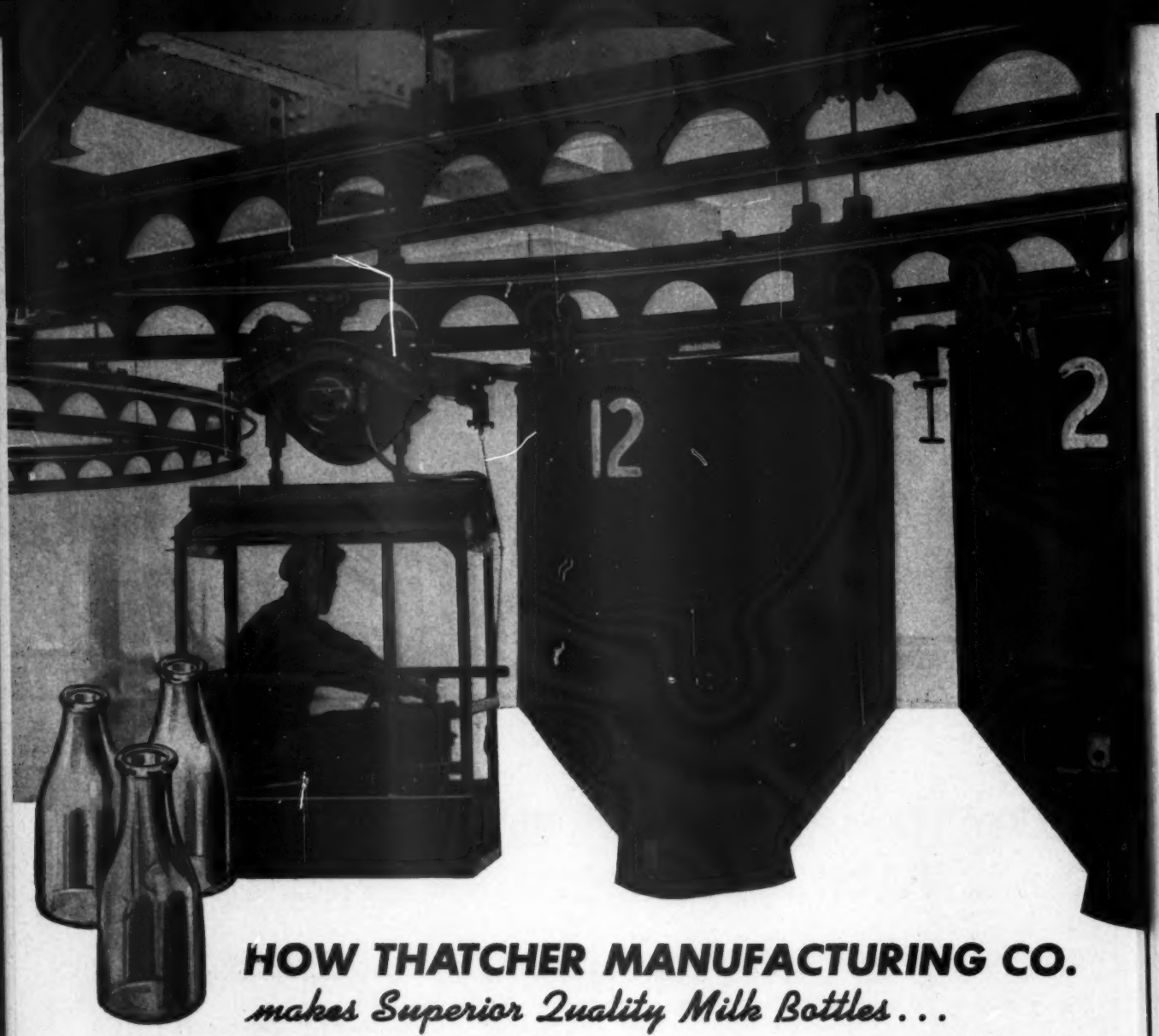

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THE GLASS INDUSTRY
VOLUME 26, NUMBER 12, DECEMBER, 1945

ADHESION TO GLASS

By W. A. WEYL*
Glass Science, State College, Pa.

Introduction

Present developments in glass technology show the trend toward the joining of glass with other materials. The combination of glass with organic high polymers forms the basis of the manufacture of safety glass and of most of the fiber glass products. The vacuum tight glass to metal seal can be considered the backbone of the manufacture of many electronic devices such as X-ray, transmitter and television tubes. Coating glass elements, such as prisms and lenses, with fluorides helps to decrease reflection losses in optical instruments. In order to increase reflection glasses are coated with metallic silver and with lead sulfide in the manufacture of mirrors. Metallic copper is deposited on the interior surface of Dewar flasks to protect their contents from infrared radiation. A number of metals such as gold, platinum and iridium are "burnt in" on glasses and glazes for decorative purposes. Aluminum metal is sprayed on the surface of glass for labeling bottles and for producing electric heating devices. The enamel industry is based on the combination of a low melting glass with steel or cast iron.

These examples may serve to indicate the great variety of manufacturing processes which involve the joining of glass with other materials principally different from glass. Glazing porcelain, too, is an operation where two materials are joined, but here the two phases are very similar in their chemical composition. Finally, we have the technique of casing opal and colored glasses, and of the production of bifocal lenses where two glasses of different optical properties are joined.

The manufacture of these items produces a great number of specific problems. Wherever two materials are joined at high temperatures, strains are produced if they have different contractions on cooling. In this case the materials have to be properly selected with respect to their expansion curves and the heat treatment of the finished ware has to be carefully controlled. The rate of cooling has to be such as to avoid detrimental stresses. This is one of the major problems in the glazing of ceramic ware, in sealing glass to metals and in enameling steel. To the manufacturer of safety glass the thermal properties of his materials are of less concern. The difference in thermal expansion is also unimportant if the two materials can be joined and used only at room temperature as in the manufacture of silver mirrors.

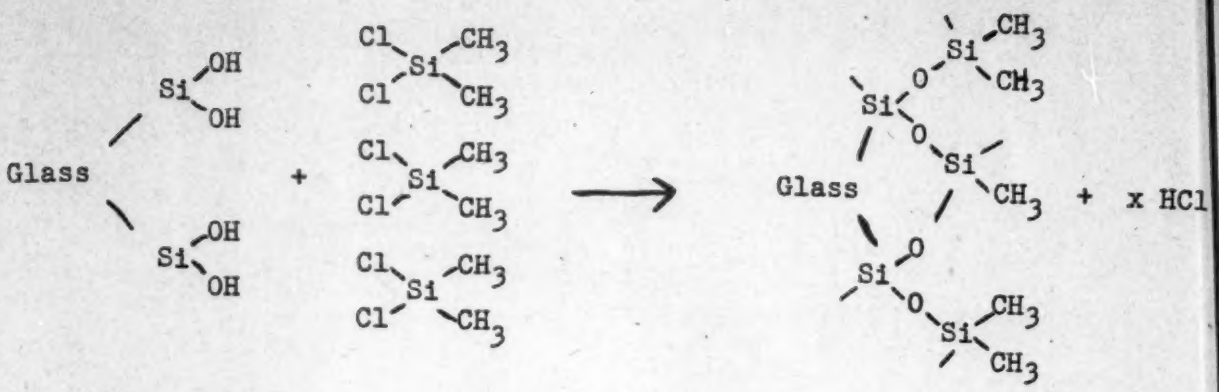
In other fields the thickness control becomes a major problem, as in the reflection-reducing optical coatings. For many purposes the joining operation has to be controlled to avoid certain chemical reactions which lead to gas evolution. In ceramic glazes the formation of a crystalline layer between body and glass is essential for good adhesion. In bifocal lenses even traces of a crystallization leads to rejection.

Each manufacturing process has its characteristic problems but all methods of joining glass with other materials have in common the problem of adhesion. What makes two otherwise incompatible materials such as a soda-lime-silicate glass and an organic high polymer stick together? This question shall be the topic of our following discussion.

There is not literature available which deals with the particular subject of adhesion to glass, but we shall try to point out the fields from which information can be obtained.

There are two principally different ways which one may use in looking for an answer to the question: What makes the two materials stick together? The one approach is based on a discussion of the forces which act between two molecules of different substances, where the term molecule is used in its widest sense, designating building units such as ions, atoms or organic molecules. The advances which recently have been made in the interpretation of intermolecular forces especially the modern concept that there is no principal difference between "physical" and "chemical" forces will prove extremely helpful.

*Director of Glass Science and Professor of Glass Technology, The Pennsylvania State College, State College, Pa.



The second approach starts with an accumulation of specific phenomena which can be observed when glasses are brought into contact with other materials. If these phenomena can be interpreted correctly they will reveal features which certain joining operations have in common. Ultimately the two ways should lead to the same goal, a basis on which to understand adhesion.

There are no principal difficulties involved in explaining the adhesion of ionic crystals such as magnesium fluoride when their vapors are condensed at a glass surface. The structure of these ionic compounds is compatible with that of glass, they are built of similar ions and the salts are soluble in the glass melt. Adhesion of MgF_2 on a clean glass surface falls under the same category as the oriented growth of ionic crystals on the fresh cleavage plane of mica or gypsum.[1] It can be considered a continuation of the structure with other building units but with the same forces holding the units together.

There are several examples for two phases being joined which differ in composition but not in the nature of the forces acting between their building elements like the casing of two glasses; "salt glazing," that is the exposure of ceramic products (bricks) to gases and vapors which form glasses at the surface of these products; and the reaction of hot glasses with the vapors and melts of metal salts. The latter may lead to two fundamentally different products depending on the nature of the transition zone. If diffusion is negligible, as in the case of titania, tin or iron compounds, a sharp transition exists between glass and the new layer. Such a combination may show iridescence or have anti-reflection properties. If the reactant contains monovalent ions such as Ag^+, Cu^+, or Tl^+ and the reaction takes place at a temperature which is sufficiently high, diffusion produces a gradual transition without light interference.

We can eliminate these cases from our present discussion, because they present no problem so far as the adhesion is concerned.

Coating a glass with "Dri-Film" also does not need particular attention in the frame of this discussion; the process of joining glass with organic silicones[2] in order to make it water repellent involves a very simple chemical reaction. Every chemist who learns about the mechanism of the "Dri-Film" reaction understands the reasons why organic silicones stick to glass. The surface layer of glass is hydrated. Instead of SiO_4 units, the surface structure contains numerous Si^{4+} ions which are connected with the interior parts of the structure in the usual way by means of oxygen ions. Towards the outside, however, they are linked to OH groups.

The reaction of such a glass surface with dimethyl silicon chloride involves an elementary chemical reaction and its product can be pictured satisfactorily by means of the symbols used to describe primary valence bonds.

Adhesion becomes a real problem only if we cannot picture the sealing of glass to other material as the result of primary valences or as the continuation of the glass structure with other building units. Outstanding in this respect is the adhesion of glass to high polymers and to metals. So far as the glass-to-metal seal is concerned we again must make a certain restriction. In many cases where we speak of glass-to-metal adhesion we probably deal with the transition, metal-metal oxide layer-glass. In this case the "abrupt change" in the building forces is probably between metal and metal oxide rather than between the oxide and the glass structure.

The Theoretical Approach

We can express formally the attraction between two molecules as the sum of three major forces and write

$$U = U_{orientation} + U_{induction} + U_{dispersion}$$

$U_{orientation}$ and $U_{induction}$ are forces which result from the electro-static attraction of ions, permanent and induced dipoles.

$U_{dispersion}$ is the attraction which results from the dispersion effects. It cannot be derived from classical physics but requires wave-mechanical treatment for its explanation. The basic idea is that even a neutral, non-polar molecule can be considered a fast rotating dipole. $U_{dispersion}$, sometimes also U, is called the van der Waal's attraction.

The influence which the three partial forces exert varies with the temperature, the nature, the size and the charge of the molecules under consideration and with their mutual position in space, as can be seen from the following brief description.

$U_{orientation}$: At high temperature the molecules rotate and as a result attraction and repulsion become equally probable. If the temperature is sufficiently low and the inertia of the molecule high, rotation ceases and changes into oscillation about an equilibrium position. Now the molecules can orient themselves. (Keesom). $U_{orientation}$ increases with a) decreasing temperature, b) polarity of the molecule, c) size of the molecule.

$U_{induction}$: Debye pointed out that not only rigid

dipoles are oriented and attracted by an electric charge but that even nonpolar molecules are subjected to attraction if they are polarizable. The induced dipole moment of a molecule is proportional to the strength of the field and to the polarizability to the molecule. In contrast to the Keesom forces which depend on the mutual orientation, the Debye forces are always negative. That means regardless of the way the molecules are oriented, they always attract and never repel each other. As a result the Debye forces $U_{induction}$ are less subjected to the influence of temperature and thermal vibrations. $U_{induction}$ increases with a) increasing polarizability, b) increasing size of the molecule.

$U_{dispersion}$: According to classical physics the e should be no attraction between two Cd atoms or a Cd atom and a He atom. Nevertheless, spectroscopy reveals that compounds of short life exist between Cd and He. Little is known about the nature of these forces. London, Slater and Kirkwood expressed:

$$U_{dispersion} = -\frac{3}{2} \cdot \frac{1}{r^6} \cdot \frac{\alpha_1 \quad \alpha_2}{\frac{1}{U_1} \quad \frac{1}{U_2}}$$, where

α_1 and α_2 are the polarizabilities of the two unexcited molecules and r their distance. U_1 and U_2 are energy values which can be calculated from optical data. (Dispersion curve). According to London, U is related to the ionization energy. Slater expressed:

$$U = \frac{n}{\alpha}$$, where n represents the number of the outer electrons and α the polarizability.

The London dispersion forces are fundamentally different from those acting between permanent and induced dipoles. They are strictly additive, they depend only on the distance between the molecules but not on their mutual orientation nor on the surrounding.

In liquids where each molecule is surrounded by other molecules, the Keesom and Debye forces cancel each other to a large extent but not the dispersion forces.

This sketchy treatment of the forces acting between two molecules indicates the importance of the polarizability. In the development of an adequate picture of the structure of glasses the polarizability of the constituents is just as important as their size and charge. For many years K. Fajans[3] and his school have called attention to the role which the polarizability of ions plays in determining the properties of a crystal (refractive index, color, density, vapor pressure). We are just beginning to evaluate the polarizability in respect to its influence on the properties of glass. The reason for this delay is that practically all our glasses are built up from noble gas ions such as O^{2-}, Si^{4+}, Na^{+}, Ca^{++}. Their polarizability is low and can be neglected for many practical purposes. However, this is not true for glasses containing very large cations (Cs^{+}, Ba^{2+}) or ions of non-noble gas character (Pb^{++}, Cd^{++}, and Zn^{++}).

The "inertness" of the soda-lime-glasses or of the alumino-phosphates is caused by the absence of ions which are strongly polarizable. In order to produce "sticking quality" or "solvent power" in respect to another material like a metal, one has to introduce polarizable ions, preferably cations with incomplete outer shells. A few examples may illustrate this statement.

1.) Enamels are low melting glasses of the borosilicate type which are used as coatings for metals such as noble metals (jewelry), steel (kitchen utensils) or cast iron (bath tubs). Adhesion to the metal is due to one of the following reasons: a) The presence of lead ions as a major constituent in the enamel. b) The presence of a specific adhesion promoting ion of the transition group: Ni^{++}, Co^{++}, Fe^{++}, Mn^{++}. c) The presence of a large polarizable ion: Sulphur. (Phosphate glasses have been made adherent to metal by the addition of sulfides.)

2.) Glass tableware made from a soda-lime-glass is not very suitable for gilding. The absence of polarizable ions is responsible for the failure of the gold film to stick to the glass surface. Experience has taught the decorator that good sticking can be achieved by "mudding" the glass, that is by treating the parts to be gilded with a mud or slip made of clay, ocher and silver or copper compounds. This operation carried out below the softening point of the glass modifies its surface and introduces silver or copper ions which have non-noble gas structures. Their presence promotes adhesion to the noble metal.

3.) For the manufacture of certain colored glasses such as silver yellow and gold or copper ruby, it is essential that the base glass exerts some solvent power upon the metal. As long as heavy lead glasses were used no difficulties were encountered. Soda-lime-glasses can be used, however, only if small quantities of tin oxide or bismuth oxide are introduced. Metallic gold is soluble only if ions of sufficient polarizability are present. Recently a glass melt of good solvent power for platinum was produced from noble gas ions only. This glass contained the large polarizable cesium ion as a major constituent. In this case the size of the cesium ion permitted the interpenetration of electrons essential for the solubility of metals.

4.) For neutral atoms also the polarizability increases with increasing size. This is brought out in the work of A. C. B. Lovell[4] who studied the stability of molecular films of alkali metals on a well "baked out," that is degassed, glass surface. The stability of these thin invisible films could be determined by measuring their electric resistances. Films which consist only of a few atomic layers deteriorate through recrystallization. Lovell found cesium films to be the most stable and the stability decreased with decreasing size of the atoms. This indicates that alkali atoms adhere more closely to glass in the order K-Rb-Cs.

5.) Adhesion of a silver mirror to soda-lime-glasses is promoted by a previous treatment of the glass surface with tin compounds. Tin ions help to bridge over the incompatibility of silver and glass. Their effect is not restricted to soda-lime-glasses but they accomplish the same adhesion between silver and plastics.

With the increase of the molecular weight the dispersion forces become more important. In times when physical chemistry dealt chiefly with substances of low molecular weight, one heard quite frequently about the "only weak van der Waal's forces" as responsible for adsorption, etc. This is not true of high polymers.

Some high polymers do not vaporize on heating but decompose, that is the chemical bonds break before the thermal motion overcomes the van der Waal's forces holding the macromolecules together.

The dispersion forces will be primarily responsible for adhesion of plastics to glass if the organic high polymer lacks specific groups such as —COOH or —CO·NH_2—groups which exert strong cohesion forces due to their polarities.

At first glance the problem of adhesion between plastics and glasses seems to be a very simple one. Adhesion between the two media can be increased by incorporating polar groups of higher chemical affinity into the polymers. Unfortunately loading a polymer with groups of this type not only increases the forces between the organic molecules and the glass but also increases the forces between the organic molecules themselves. The latter reduces ductility and makes the polymer strong but brittle.

If one tries to follow the problem of adhesion through by means of the purely theoretical treatment of intermolecular attraction forces, one meets with a major obstacle. The theory of the structures of solids is not as uniform as one would wish for calculating forces acting between two different types of solids such as metals and ionic crystals. In other words, there exists a good theoretical picture of the structure of metals based on the Drude-Lorentz concept of the free electron gas, a theory which has been modified by Sommerfeld by introducing the principles of quantum theory. There exists also a well progressed picture of the structure of ionic crystals and of simple silicate glasses. Both theories have been developed to suit the purposes of their respective fields but they are based on slightly different concepts and the gap which has developed between the two concepts has not yet been closed. Once the same concepts are used for interpreting the structures of all types of solid matter, the formal approach to the development of a theory of adhesion will be a more useful tool than it is now.

The Practical Approach

In following the way indicated by a formal treatment of the forces acting between two different molecules, we will soon find ourselves surrounded by problems to which no solution is yet available. The value of the formal approach lies in the discovery of general features such as the polarizability of the adhering phases or the influence which temperature may exert. Its limitation is that it gives us only the first approximation but does not permit the comparison of two similar ions on a quantitative basis. The mathematical treatment of chemical forces has not yet reached a stage where it can be applied to individual elements and bring out the chemical characteristics of, let us say, arsenic and antimony. We may be able to explain why large ions, especially ions with incomplete outer shells enhance the adhesion or the solvent power of a glass in respect to metals but we cannot yet predict which ion, bismuth, lead or tin, raises the solubility of copper in a soda-lime-glass sufficiently to produce a satisfactory copper ruby. We cannot explain why the solubility of gold in a glass is raised by a fraction of one per cent of tin oxide to about the same value as by 10 per cent lead oxide.

Knowledge of the individual chemical properties and specific reactions of the elements is still indispensable and no mathematical formula has been found to take its place. The experiment has not lost its predominant role in research, but the selection of the experiment should be guided by the principles which we discussed previously.

The literature offers a great number of experiments which can be considered pertinent to the problem of adhesion. Let us restrict ourselves in this paper to the forces acting between glasses and metallic phases. These forces are manifest in those phenomena where glasses adhere to metals or where they exert a solvent power upon them. From this point of view we have to discuss the group of colored glasses which owe their light absorption to metallic phases in a state of fine subdivision. An extensive discussion of this subject will appear in the near future in the *Journal of the British Society of Glass Technology* as a part of the writer's monograph on "Colored Glass."

Silicate glasses are salts. The forces acting between metals and glasses can therefore be discussed from the broader viewpoint of the interaction between salts and metals.[5] Research in this field was stimulated by the electro-chemical industry especially by the production of metals from their salts by electrolysis. It was recognized that some metals such as cadmium, tin, lead and bismuth were slightly soluble in their chlorides. Electrolysis produces the metal at the cathode where a part of it dissolves in the fused salt and reaches the anode by diffusion. There it recombines with the chlorine, and this reaction decreases the efficiency of the process. A thorough understanding of the phenomena involving the solubility of metals in fused salts and glasses was greatly delayed by the dominating influence which W. Nernst had in the field of physical chemistry. In his authoritative book on Physical Chemistry, Nernst expressed the view that metals are soluble only in metals and alloys. Only a few chemists, therefore, dared to talk about the solubility of metals in other media and even the book on this subject of Lorenz and Eitel (1926)[5a] entitled "Pyrosols" stresses the colloidal angle much more than the true solubility. This was at the time when one preferred to speak about "subchloride" formation rather than of the solubility of a metal in a chloride. Today we know that metals can be soluble in ammonia or in fused salts and glass melts. We realize that Nernst's statement limiting their solubility to metallic phases has to be modified. Metallic phases are the only ones which can dissolve metals and let them retain their metallic structure and properties such as high electric conductivity, high reflectivity and strong light absorption.

In all other solvents metals enter into solution by assuming the properties of their vapors, thus losing their electric conductivity and reflection.

We have learned that the highly polarizable ions such as Pb^{++} must be considered responsible for the forces keeping a metal atom in solution. Removing this type of ion from a melt results in decreased solvent power. This is brought out in the following data giving the solubility of metallic lead in the binary system $PbCl_2$—KCl.[5b] The addition of KCl produces a structure change. The Pb^{++} with their high ionic potential surround themselves with Cl^- forming a complex ion. The complex ion does

(*Continued on page* 574)

THE SCIENTIFIC MEASUREMENT OF COLOR

By ALLAN P. SARGENT

The question of the relative value of pure science and applied science used to be debated with great vigor, but today, in Great Britain at least, it is regarded as rather pointless. According to the modern view all knowledge is one, and the importance of any addition to knowledge does not depend upon whether it resulted from researches in pure science or from experiments made with a practical end in view. Over and over again discoveries which seemed to have a merely theoretical value have been turned to useful account, and just as frequently the inventions produced for industrial purposes have thrown light upon the fundamental problems of science.

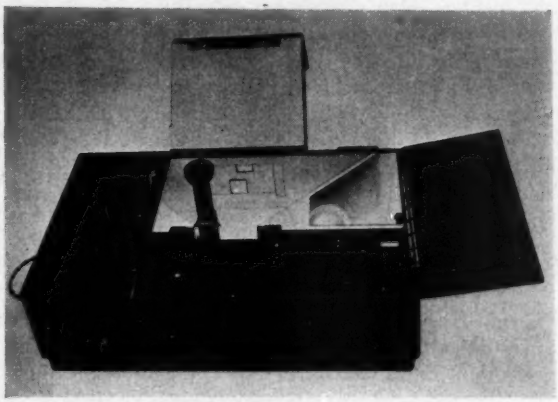


Fig. 1. The Lovibond Tintometer, an aid in quality control where color of the product can be used as a guide.

An example of the later process is afforded by the Lovibond system of color measurement. In 1884 a British brewer, J. W. Lovibond, devised an instrument for measuring and recording the color of the liquors used in the brewing industry. Color is an important guide to quality in the manufacture of fermented liquor, but until the invention of the Lovibond "Tintometer," Fig. 1, the brewer had no means of determining and accurately controlling this factor. His original instrument consisted of a series of brown glass slides graded from light to dark; these slides provided a standard color scale and they were so numbered that the scale was additive—that is to say, a slide value of ten units was equivalent to two slides of five units value or to any other slides totalling ten units. Thus the various shades of color experienced in the process of brewing were expressed quantitatively and exact science replaced uncertain observation.

The success of the Tintometer in the brewing industry led Mr. Lovibond to develop a form which could be applied to measuring and recording the colors of products used in other industries. Instead of graded brown slides he employed series of red, blue, and yellow slides which, by their various combinations, embraced every shade of color. Not only did this ingenious instrument come rapidly into general use in numerous industries but it also contributed to the scientific study of color. Its essential features are a light source, a series of colored glass slides which form the standards of reference, and a means of eliminating all light except that reflected or transmitted by the sample under observation and by the color standards. From the point of view of the user the Tintometer is simplicity itself. When the sample is placed in position in the instrument and viewed through the eyepiece, one half of the field of view appears colored by the sample. Slides are then introduced into the other half of the field of view by merely moving pointers on racks carrying various slides, and the slides are adjusted until the two halves of the field of view appear equal in tint and brightness. The number of the tint can then be determined by reference to the numerical color scale. Users soon become familiar with the system and learn to visualize colors from the Tintometer readings alone. It would, indeed, be possible to replace the descriptive terms used for colors

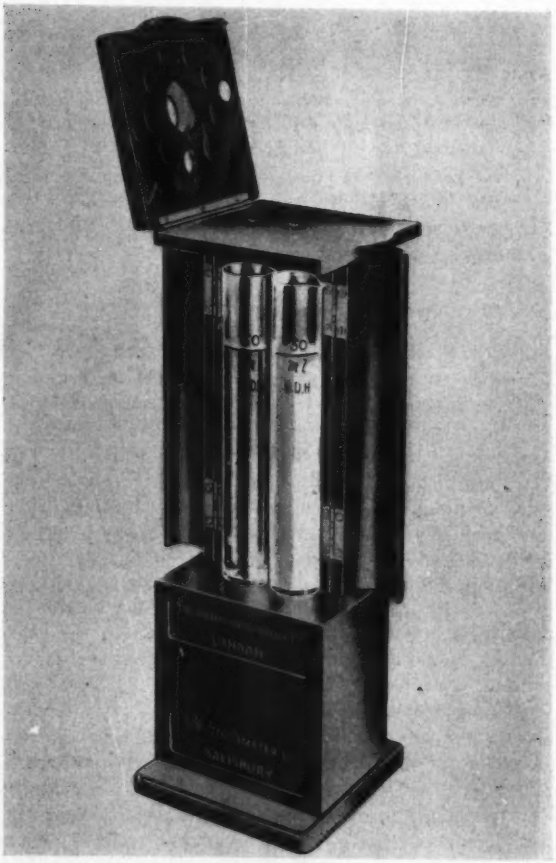


Fig. 2. The Lovibond Nesslerizer employing permanent color glasses matched with colors of solutions of known strength.

in the fashion world and in the paint industry by numbers alone.

In 1931 the Commission Internationale de l'Eclairage adopted certain rules for the measurement and specification of colors. As it is practically impossible to adapt the original Lovibond method to these rules, a modification, known as the Lovibond-Schofield system, was introduced whereby the conversion of the Lovibond color scale to the C.I.E. scale can be readily effected.

The development of the Tintometer has led to the production of various interesting accessories for color measurement. One is the Lovibond Nessleriser, Fig. 2, an instrument by which the color of certain liquids can be determined without the necessity of preparing large numbers of standard solutions for purposes of comparison. The standards used in the Nessleriser are permanent color glasses which have been matched with the colors of the solutions of known strength.

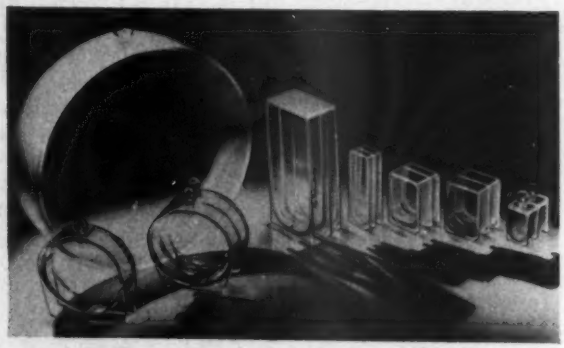


Fig. 3. Optical glass vessels for all types of colormetric and photometric apparatus.

Another accessory is the glass cell, Fig. 3, for holding a liquid during examination for color. The glass must have special optical properties so that it does not introduce any color distortion; it must also be free from strain and resistant to chemical action. Previous to the present war optical cells of this type constituted a German monopoly in Great Britain; today the makers of Lovibond Tintometers produce these cells in an endless variety of forms and of better quality than the cells previously imported. One of two processes—sintering or fusing—is used in building up the cells. The sections of rectangular forms are sintered, the process involving the use of a special vitreous cement which, when heated in a furnace, provides a homogeneous glass-to-glass joint without any distortion of the faces. Circular and other non-rectangular cells have fused joints, the surfaces being welded together solidly. Although the establishment of this new British industry called for intensive research and experiment, and the training of personnel, it was achieved rapidly and with complete success.

An associated industry also new to Great Britain is the manufacture of the plunger-type colorimeter for comparing the concentration of two solutions by measuring the heights of the columns of liquid when their colors appear equal.

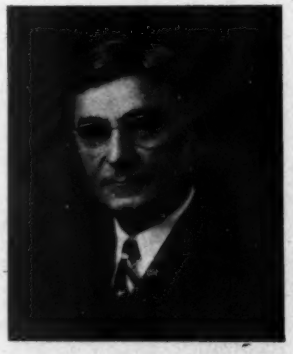
The word sintered is applied to quite a different type of glassware which is interesting in itself and also because it represents another German monopoly broken since the war by British enterprise. This glassware is composed of selected glass powders heated in moulds until the granules adhere in a porous mass which can be used for an immense variety of filtering purposes. Its applications include pressure filters for petrol (gasoline) and other volatile liquids, filters for microchemical apparatus, the removal of bacteria from liquids, the washing and filtration of gas, and the silent injection of steam into water. Filters of this kind have also been employed in the production of Penicillin.

OVERMYER MOULD TWENTY-FIVE YEARS OLD

On November 23, the Overmyer Mould Company of Winchester, Indiana, celebrated its twenty-fifth anniversary.

There are many concerns in the glass industry whose corporate existence antedates Overmyer Mould by a great many years, but with Overmyer this anniversary marks the development of a large and important concern which started from scratch only twenty-five years ago. Also to be noted is that C. P. Overmyer, Sr.,—Chet—founder of the company, is still very much its directing genius.

Space does not permit a detailed review of the growth of this company, but today Overmyer Industries is comprised of the main plant and executive headquarters in Winchester, Indiana; the Overmyer Mould Company of Pennsylvania, its pressed ware and novelty division; and Omco Products Corporation, Springfield, Ohio, manufacturing screw machine products. Now in the process of construction is a plant in Los Angeles which will be known as Overmyer Mould Company of California.



With regard to this project, the company reports that Mort Longnecker, who for many years was actively engaged in managerial affairs in the home office, is now in California supervising the work on this new plant.

Outstanding among the many tributes offered on the company's twenty-fifth birthday is one which appears in the concern's house organ, Omco News. It is a brief article written by daughter, Harriet, entitled "My Dad." It is remarkable for its sincerity and evaluation of the man, Chet Overmyer. To these many messages of goodwill, THE GLASS INDUSTRY extends its congratulations and best wishes for continued success.

IMPORTANT DATA CAN BE OBTAINED FROM STUDY OF GERMAN GLASS PLANTS

Congress is urged to provide additional funds for continuation of Department of Commerce Glass Investigating Committee

By H. L. DILLINGHAM
Business Manager, American Glassware Association

A tangible and perhaps the only direct benefit the United States glass industry can derive from the winning of the war is having access to the "know-how" for producing certain types of glass which Germany predominantly sold in the prewar period. It is generally admitted by informed persons that for years the Germans have been proficient in developing machinery, methods, and formulae for producing glass. All of their accomplishments now are available to United States glass manufacturers if they will accept the opportunity offered by the United States Department of Commerce to inspect German glass factories and interview members of their technical and scientific staffs.

Before V-E Day, the U. S. Foreign Economic Administration cooperated with the Allied Military Intelligence group by sending trained industry scientists as investigators to German factories as quickly as the areas in which the factories were located, were captured. They secured abundant and precise information on German methods for producing war material, much of which was new to this country. The data collected was most helpful to allied producers and contributed greatly toward final victory.

At the close of the war, plans already had been laid to extend this investigation of German machines, factory methods, and formulae to include plants producing civilian products and to report this information to United States manufacturers of durable and non-durable goods for civilian use. Many of these investigators' reports now are available on industries that have been surveyed or are in the process of being investigated. Naturally priority in this activity was given to the more strategic industries, such as rubber, bomb propelling chemicals, and synthetic oil. The information these investigating teams have secured has been screened in Allied offices in London and then sent to various government departments for distribution to United States and British manufacturers. Over 300 reports are now available covering many industries, and an index list of them has been published by the U. S. Department of Commerce, which may be obtained upon request to the Office of the Publication Board.

After the collapse of Germany, the Industrial Intelligence work of the Foreign Economic Administration was transferred to Department of Commerce control with the understanding that this work would continue only as long as the dollar appropriation to pay for it was available.

Realizing the importance of the glass industry, both in this country and Germany, a glass investigating committee, composed of three industry representatives, is being formed by the Department of Commerce in conjunction with the Joint Chief of Staff Intelligence Section. The committee members will visit German glass factories and secure data on definite questions that have been compiled by U. S. manufacturers seeking knowledge of certain processes, formulae, and methods which the Germans developed.

Mr. C. J. Uhrmann, Vice President of the Imperial Glass Corporation, one of the appointed members of this glass committee, is already in Germany on this assignment. His report, and those of the other committee members, on their return, will be made available to all United States glass manufacturers if Congress appropriates the funds necessary to continue the collection and dissemination of this valuable information.

The present appropriation expires December 31, 1945. There now is a bill before Congress to provide additional funds for the continuation of this work which if not authorized, will deprive all U. S. industry, and in particular glass manufacturers, of valuable data that would help them to produce glassware previously furnished to prewar world markets by the Germans. The glass industry, therefore, should actively urge the passage of this bill.

It would be short-sighted for Congress to fail to make this appropriation. The expense is relatively small, involving only the cost of transportation, housing, and food for committee members while in Europe, since the personnel is provided in most instances by industry without any salary obligation by the Government.

Billions have been spent to win the war. Industry contributed heavily in both dollars and the supply of materiel for the war. Congress can show its appreciation of the situation by providing funds to continue the scientific and industrial investigations which have been started. United States manufacturers then would be able to augment there present knowledge with all that Germany has accomplished and, in some degree, be repaid for the "all-out" effort and support that it rendered during the war; and U. S. commerce would be increased, both in export and in domestic trade during the postwar era.

• The Chas. Taylor Sons Company has announced the appointment of Refractories Engineering and Supplies Company as its exclusive representatives in Canada. The company is operated under the management of J. L. Spence and G. W. Paterson, both of whom were formerly associated with Canadian Refractories, Ltd.

INVENTIONS AND INVENTORS

A Summary of Patents of Interest to the Glass Industry Issued During October

Furnaces

A new method and apparatus for feeding batch and making glass is shown in patent No. 2,388,274, assigned to Hartford-Empire Company by Aaron K. Lyle. This mechanism is particularly adapted for end-fired tanks where there is often not room for a regular batch feeder on the rear wall. It has been the previous custom to feed the batch to such a furnace straight in through a side wall, but this was unsatisfactory. This patent proposes to feed the batch through one, or preferably both side walls, but in a direction inclined toward the back wall. This is clearly shown in Fig. 1 which is a horizontal section of an end-fired tank. The figure shows a tank of usual construction, having end ports 4 and burners 5. The fire is reversed as usual, and the path of the fire is indicated approximately by the line 7. This causes the "hot spot" to be located as indicated by the circle 8.

A doghouse 9 is provided on each side of the tank, preferably closer to the "hot spot" 8 than to the rear wall of the tank, although this location may be varied. These doghouses may be such as shown in Lyle's earlier patent No. 2,246,375. Each doghouse has a batch feeder 11 of any usual construction, but preferably as shown in patent

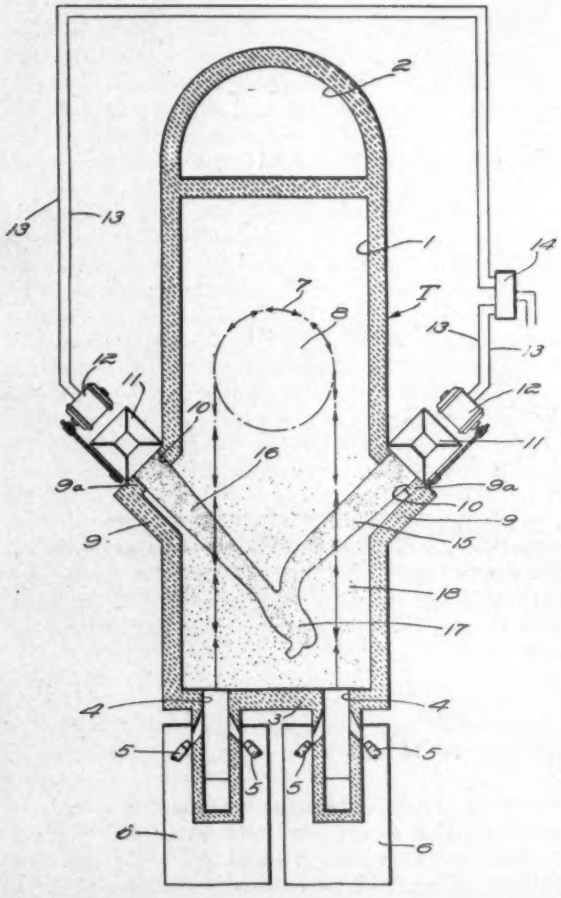


Fig. 1. Hartford-Empire Batch Feeding Apparatus, patent No. 2,388,274.

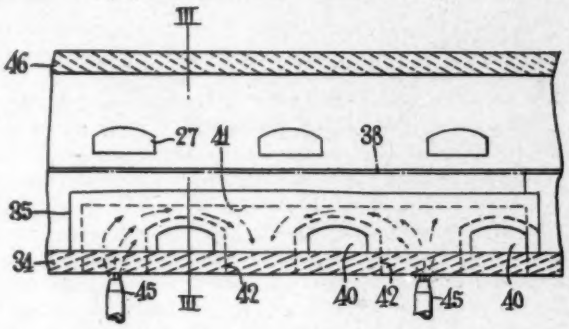


Fig. 2. Patent No. 2,387,880, Pittsburgh Plate Glass Company Tank.

No. 1,941,897, granted to E. O. Hiller. These batch feeders are driven by motors 12 which are operated in any desired sequence by a control mechanism indicated at 14. Such a control mechanism is disclosed in Lyle's former patent above mentioned. Reference is made to a pending application filed in the names of Harold W. McIntosh and Albert S. Crandon, which shows another control mechanism. Both of Lyle's patents and this patent application all relate to what is known as the Hartford Batch Feeding System. This system provides means for operating the two batch feeders simultaneously, or in any desired sequence. For the purpose of illustration, Fig. 1 shows two masses of batch, 15 and 16, extending toward the rear wall of the tank. The partly melted batch is indicated by the stippled portion 18.

Patent No. 2,387,880 was assigned to Pittsburgh Plate Glass Company by George D. Campbell. The object of the invention is to provide a tank which will prevent impurities or batch which is not thoroughly melted from being drawn out into window glass which will not be of good quality.

As shown in Fig. 2, a tank of the usual construction, having ports 27 and a bottom 34, is provided with what is called a "fence" parallel and slightly spaced from each side wall. The top of the fence is below the metal line and it is provided with a series of spaced, arched openings 40 through which the glass can pass. This fence is hollow so as to form a chamber 41 throughout its length and this chamber communicates with openings 42 formed in the bottom of the tank. The patent states that fluid can be circulated through the openings 42 by means of conduits 45. No doubt this would be a heating fluid, but it is not so stated. In any event, these two fences set up convection and eddy currents which mix the poorer quality glass adjacent to the side walls, with the better quality glass, and direct it back to the hotter portion of the tank to melt it more thoroughly.

Patent No. 2,387,222 is an invention by Joseph W.

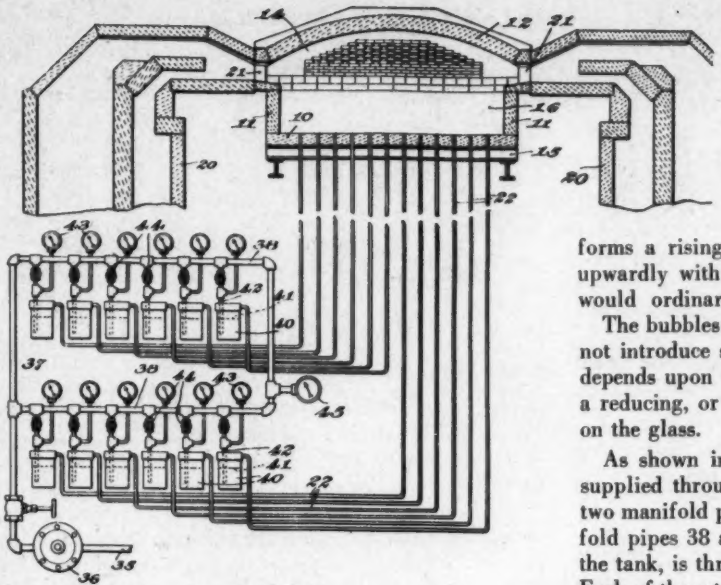


Fig. 3. Wright Patent No. 2,387,222 on a method of refining glass.

Wright, assignor to Owens-Illinois Glass Company. This patent proposes to hasten the fining of glass by controlling the convection currents. This is done by causing a row of bubbles to pass upwardly through the glass in a line transversely of the tank so that these bubbles will carry the seeds and other inhomogeneous matter to the surface of the glass, where a remelting and mixing will take place.

As shown in Fig. 3, there appears a cross section of a tank having a floor 10, side-walls 11 and a roof 12. The tank is of the usual construction, having bridge-wall 16 separating the melting compartment from the fining compartment and ports 21 connected as usual with regenerators 20.

A row of pipes 22 extend upwardly through the floor of the furnace and gas is discharged from these in the form of bubbles rising at regular and controllable intervals. Of course, these pipes have to be provided at their discharge ends with means to resist the action of the molten glass. This row of pipes is preferably arranged nearer to the bridge-wall than to the back wall of the tank. This forms a rising curtain of molten glass which is drawn upwardly with the bubbles, thus lifting the glass which would ordinarily remain on the bottom of the tank.

The bubbles are comparatively large and, therefore, do not introduce seeds into the glass. The type of gas used depends upon whether it is desired to have an oxidizing, a reducing, or a neutral gas for the purpose of reacting on the glass.

As shown in Fig. 3, air or any other desired gas is supplied through a pipe 35 and a reducing valve 36 to two manifold pipes 38. The connection between the manifold pipes 38 and the pipes 22, leading to the bottom of the tank, is through what is called a "bubbling tube" 40. Each of these tubes is partly filled with oil or other liquid 41. The air from the manifold 38 enters the bubbling tube by a pipe 42 which dips into oil in the tube. A pressure gage and regulating valve is provided to control the flow of air to each tube. The rate of discharge of air to the glass will be apparent by observing the rate of formation of bubbles in the bubbling tubes. Apparatus has been

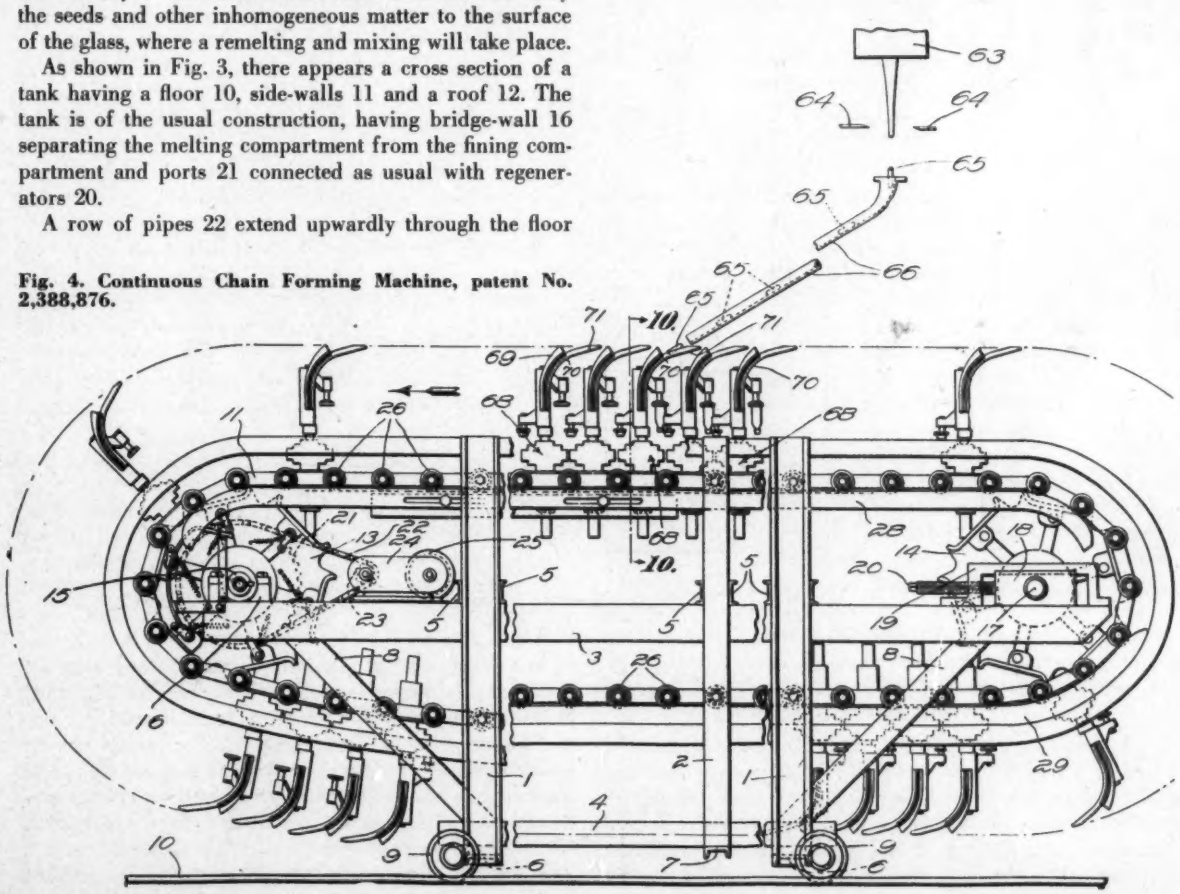


Fig. 4. Continuous Chain Forming Machine, patent No. 2,388,876.

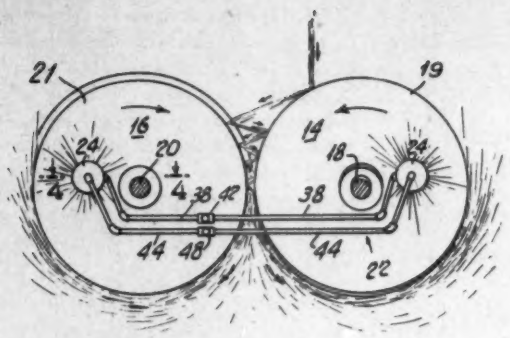


Fig. 5. Pittsburgh Plate Glass Sheet Drawing Machine, patent No. 2,387,886.

tried with satisfactory results with bubbles discharging at the rate of anywhere from 6 to 100 per minute.

Feeding and Forming

Hartford-Empire is the owner of patent No. 2,388,876 an invention of Algy J. Smith. The most outstanding characteristic of this machine is that a continuously moving chain carries a series of complete bottle forming units. As shown in Fig. 4, a framework is mounted on wheels 9, supported by a track 10, so that the machine may be conveniently moved. The continuously moving chain indicated at 11 passes around a driving sprocket 13 and idle sprocket 14. The sprocket 13 is driven by a speed changing device 24.

One feature of this invention, which is not clearly shown in the figure, relates to the means by which air pressure can be supplied to all of the bottle forming units carried by the chain at all times.

This patent discloses a stream feeder 63 having a pair of rapidly operating shears 64. The severed charges pass down a chute 66 to successive bottle forming units 68. Each of these units includes the necessary parts for forming a complete bottle such as the blank mold, blow mold, neck pin, etc. Each unit also carries a deflector 69 to guide the charge from the chute 65 to the blank mold. This patent carries 36 claims and it is impossible to describe all of the various features in a brief abstract.

Glass Composition

A glass composition particularly useful in the manufacture of electric lamps has been invented by John H. Partridge of England, and assigned to the General Electric Company.

As shown in this patent No. 2,388,866, it has been found that the use of strontium oxide makes it possible to reduce the amount of lead oxide which otherwise would be around 30%. In accordance with this patent, a glass is provided containing at least 2% of strontium oxide and not more than 20% of lead oxide. Two examples of this lead glass composition are as follows:

	1	2
SiO_2	58.8 per cent	57.6 per cent
PbO	19.9 "	9.3 "
Al_2O_3	0.74 "	0.88 "
BaO	2.88 "	2.68 "
SrO	2.52 "	7.81 "
MgO	1.23 "	4.35 "
B_2O_3	1.00 "	
Na_2O	5.9 "	8.58 "
K_2O	7.2 "	5.86 "
TiO_2	— —	9.5 "

Glass Wool and Fiber

The Johns-Manville Corporation is the owner of patent No. 2,388,935, an invention of Edward R. Powell. This is a machine for making mineral wool which may be formed from rock, slag, glass or other material. As shown in Fig. 5, two high speed spinners 14 and 16 are mounted on adjacent shafts 18 and 20 which are slightly out of parallel. The molten material drops on the spinner 14 as shown by the arrows, where it starts being made into fibers, which operation is continued when the material is thrown onto the other spinner 16. The speed suggested for the rotators is 3800 to 4600 r.p.m.

The binding material is applied to the fibers while they are being formed, or immediately afterwards. Bakelite

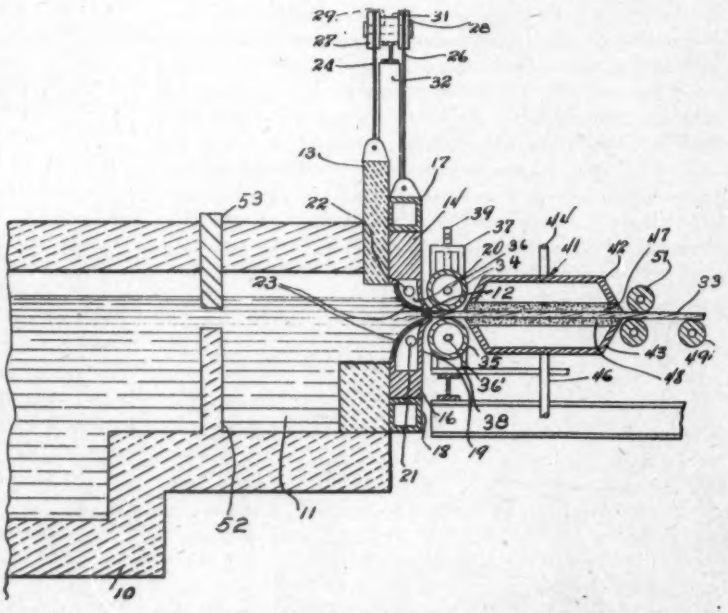


Fig. 6. Machine for making Mineral Wool, patent No. 2,388,935.

resin is suggested as a suitable binder. The means for applying this binder is indicated generally at 22. Spray heads 24 discharge high pressure steam. The binder material is supplied by lines 32 and 38. The spray heads 24 have adjustable discharge openings so that the volume of binder material may be readily adjusted to suit the material being made, and to provide a uniform distribution of the binder in droplet form throughout the fibers.

(*Continued on page* 582)

GI Research Digest

Practical Interpretations of Glass Technology

The Stress-Optical Coefficient of Glasses

A knowledge of the stress-optical coefficient of glass is necessary in calculations of the internal stresses set up by the application of mechanical force. Balmforth and Holland (*Journal of the Society of Glass Technology*, April 1945) review earlier measurements and describe the results of a new investigation.

The glasses used in this work were: 1) a series of soda-lime-silica glasses in which CaO progressively replaced Na_2O on a molecular basis in a parent glass of the general formula $6SiO_2$ $(2\text{-}x)$ $Na_2O x CaO$; and 2) twelve commercial optical glasses containing varying percentages of PbO (seven glasses) and BaO (five glasses).

The progressive replacement of soda by lime in this parent glass resulted in a small but significant increase in the stress-optical coefficient. This data is reproduced in Table I. The results of the measurements on the lead oxide-containing glasses were in good agreement with the general results for similar glasses published by F. Pockels in 1902 and again indicated that a glass of approximately 75 per cent PbO content would have a zero stress-optical coefficient.

In the case of the barium oxide-containing glasses, it was found that BaO reduces the stress-optical coefficient, but the glasses tested, being commercial glasses, did not follow any ordered change of composition, and it was not possible to correlate precisely the stress-optical coefficient with change in barium oxide content.

TABLE I

Glass No.	SiO_2	Na_2O	CaO	R_2O_3	Loss on Ignition	Stress-optical Coefficient
100	73.25	24.15	—	0.22	0.95	2.59
102	72.71	23.78	2.61	0.23	0.63	2.54
103	73.94	21.63	3.61	0.28	0.51	2.62
104	73.54	20.10	4.95	0.29	0.43	2.61
104/S	73.93	18.90	5.21	0.49	0.43	2.63
106	73.82	17.70	7.18	0.28	0.34	2.67
106/S	74.35	16.38	7.56	0.48	0.34	2.70
108	74.68	14.73	9.70	0.26	0.32	2.70
109	74.84	13.48	10.86	0.26	0.31	2.70
110	74.88	12.20	12.23	0.28	0.31	2.71

Note on Silicon Stones in Glass

In the February, 1945 issue of the *Journal of the Society of Glass Technology*, Gould, Davies and Holland report on an unusual glass stone. During the operation of a tank furnace supplying glass to a continuous plate glass machine, trouble was experienced with a siege of stones of an unusual character; the stones being black, roughly-spherical in shape and varying in size from particles to spheres of about ⅛ inch in diameter looking much like small ball bearings. The stones were of metallic appearance, hard, brittle, non-magnetic, resisted oxidation, were good electrical conductors, resisted attack by acids and had a density of 2.36. Reaction occurred with molten sodium carbonate accompanied by burning. Reaction with sodium hydroxide solution led to the evolution of hydrogen. Chemical analysis of these stones indicated that they contained 92 per cent silicon. These tests, plus X-ray examination, led to the belief that the stones were composed of elementary silicon.

The cullet used in this furnace was contaminated with many aluminum milk-bottle caps and as the reduction of silica by aluminum is one of the known methods of producing silicon, it was suspected that such a reaction was taking place in the furnace. An experimental pot melt in which the aluminum milk-bottle caps were intentionally introduced in with the batch produced a small amount of silicon. The removal of the milk-bottle caps from the cullet eliminated the stones and confirmed the theory.

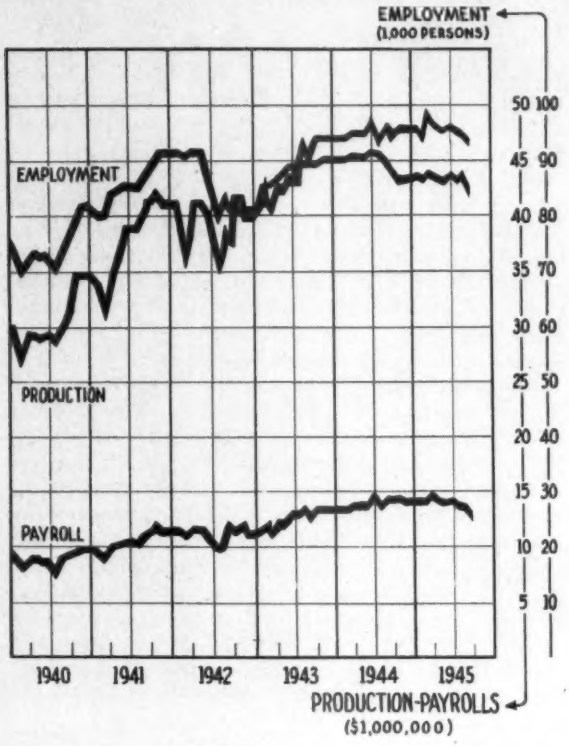
The Influence of Boric Oxide on the Crystallization of a Soda-Potash-Lime-Silica Glass

G. E. Walker (February, 1945, *Journal of the Society of Glass Technology*) reports on the study of the devitrification properties of a series of glasses of the Kavalier type as determined by the temperature gradient method. It was found that the substitution of boric oxide for silica in the series of glasses of percentage composition: $(75.82\text{-}x)$ SiO_2 xB_2O_3, 8.56 CaO, 6.86 Na_2O, 7.90 K_2O caused a reduction in the liquidus temperature from 1100°C. to a minimum of 875°C. at 5.44 per cent boric oxide. Subsequent additions caused a slight rise in temperature to 890°C., followed by a further drop to 830°C. at 22.54 per cent B_2O_3. The maximum rate of crystal growth for the different glasses reflected quite closely the differences in liquidus-temperature, values of 0.48, 0.05, 0.12 and 0.03 μ per minute being found for the parent glass and those containing 5.44, 9.58 and 22.54 per cent boric oxide, respectively. The minimum liquidus-temperature and the rate of devitrification at about 5 per cent boric oxide were associated with a change in the primary phase from tridymite to devitrite, and corresponded closely with a similar change found by G. W. Morey on adding varying amounts of boric oxide to a pure soda-lime-silica glass.

• The Plaskon Division of Libbey-Owens-Ford Glass Company plans to start a $5,000,000 construction program in the near future. It it hoped that construction of the new facilities will be completed by late July.

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



September figures showed an approximate 3 per cent decrease of activity in the glass industry from that reported for August. As indicated by the Production Index, production for September was $43,600,000, as compared to $45,300,000 for August and $47,000,000 for September 1944. Output for the first three quarters of 1945 was $420,900,000, comparing with $428,000,000 for the same nine months of 1944 — a decrease of approximately 1½ per cent.

Employment and payrolls: The total number of persons employed in the glass industry for the month of September was 84,500 persons, as compared to 87,200 during August and 88,300 during September 1944.

Payrolls for September were estimated to be $11,850,000 which is about 3 per cent less than the figure for August which was reported to be $12,300,000. September 1944 payrolls were $14,500,000. The three-quarter period of 1945 showed a total of $119,850,000 paid out in salaries during 1945.

Glass container production for October 1945 was reported to be 9,847,011 gross. This is an approximate 9 per cent rise above the figure, 8,991,084 gross, reported for September. October 1944 reports showed a production of 8,600,671 gross, or about 14 per cent less than for October 1945. During the first ten months of 1945, glass container production rose to 87,861,455 gross, as compared to 84,157,944 gross for the same 1944 period — an approximate 4 per cent increase.

Shipments of glass containers during October totalled 10,077,794 gross in comparison with 8,949,888 gross shipped during September and 8,187,346 shipped during October 1944. This indicates an approximate 12 per cent rise over September and 23 per cent over October 1944. Total shipments reported for the first ten months of 1945 were 89,677,978 gross as compared to 81,268,557 gross during the same period in 1944.

Inventories on glass containers for October were 3,786,132 gross, showing a slight drop from September and an approximate 29 per cent drop from October 1944.

Plate glass production for the month of October 1945, as reported by the Hughes Statistical Bureau, was 7,334,978 sq. ft., as compared to 10,353,520 sq. ft. produced in the preceding month, September, and 9,104,848 sq. ft. produced in the corresponding month last year, October

(*Continued on page* 570)

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures Are in Gross)

		Production Oct., 1945	*Stocks Oct.,* 1945
Foods; Medical & Health Supplies; Chemicals, Household, Industrials; Toiletries & Cosmetics	Narrow Neck	3,278,470	1,712,259
	Wide Mouth	3,566,783	927,991
Dairy Products		340,087	175,639
Home Canning		130,580	244,298
Beverages, Returnable		551,329	322,496
Beverages, Non-returnable			
Beer, Returnable		383,135	93,286
Beer, non-returnable		349,605	35,752
Liquors		990,292	194,157
Wines		169,599	71,348
Packers' Tumblers		87,131	8,906
Total		9,847,011	3,786,132

GLASS CONTAINER SHIPMENTS

(All Figures Are in Gross)

Narrow Neck Containers	*Oct.,* 1945
Foods	855,391
Medicinal & Health Supplies	1,127,988
Chemical, Household, Industrials	689,949
Beverages, Returnable	599,944
Beverages, Non-returnable	
Beer, Returnable	357,686
Beer, Non-returnable	371,837
Liquors	961,296
Wines	165,523
Toiletries & Cosmetics	618,384
Sub-Total (Narrow)	5,747,998
Wide Mouth Containers	
Foods	2,894,724
Dairy Products	334,899
Home Canning	89,510
Medicinal & Health Supplies	371,048
Chemical, Household, Industrials	146,708
Toiletries & Cosmetics	117,991
Packers' Tumblers	95,699
Sub-Total (Wide Mouth)	4,050,579
Total Domestic	9,798,577
Export Shipments	279,217
Total Shipments	10,077,794

NEW EQUIPMENT AND SUPPLIES

BROWN DEVELOPS NEW PROTECTING TUBES

The Brown Instrument Company, Philadelphia, Pa., has announced improved cast iron thermocouple protecting tubes that are said to meet advanced requirements of the chemical, metallurgical and die casting industries.

The new tubes have a uniform wall thickness to within plus or minus one thirty-second of an inch and have better surface finishes. They are cast with both ends open, permitting positive support for the core at each end. One end is closed with a cast iron plug, welded in place with a cast iron filler rod, the opposite end being threaded for a one inch standard pipe.

The tubes are available at lower prices than previous types, have an inside diameter of 13/16 inches; outside diameter of 1 3/8 inches; wall thickness of 9/32 inches; a minimum top thickness of 9/32 inches, and weighs 4.5 pounds.

COMPLETE NEW LINE OF ELECTRODE HOLDERS

A complete new line of air cooled carbon electrode holders has just been presented by the Tweco Products Company, Wichita 1, Kansas. The line includes four sizes: 150, 200, 300 and 500 ampere models.

Positive "Hol-Grip" design with ample length and ventilation are features of the new line. The average carbon arc welding job is done with either the 13½ ounce 150 ampere holder or the 20 ounce 200 ampere unit. These two units are furnished optionally with or without special "quick-attach" whip cables for short jobs. The 300 and 500 ampere models are suitable for heavy welding and cutting jobs.

YALE ADDS TO LINE

The Yale & Towne Manufacturing Company, Philadelphia 24, Pa., has recently added a Worksaver Electric Truck to its line of materials handling machinery. The new truck is compact and easily controlled and has a capacity up to three tons.

The truck has an elevating unit and a drive motor, both of which operate from a lead or alkaline battery housed in a compartment which is part of the truck chassis. The compartment has a hinged cover and removable sides for convenient charging and change of batteries.

The Worksaver is available in two types: the platform which is designed to handle single unit loads up to 6,000 pounds and the pallet which can handle single or multi-unit loads which are palletized up to 4,000 pounds.

Several safety features are found on the new truck. When the cam controls on the steering handle are at neutral, the brake is on. When the steering handle is in vertical or horizontal position, the brake is automatically applied and the power is cut off. In this way, the operator has complete control of the truck on ramps, but in the event that the handle is dropped by accident, the truck is halted immediately.

NAT'L RADIATOR DEVELOPS NEW COOLER ELEMENT

The National Radiator Company, Johnstown, Pa., has developed a new U-Cast Hairpin Cooler Element which is used for cooling any liquid. It is especially adapted for cooling acids or strong alkalies under extreme conditions that usually result in solutions attacking other metals.

The new elements in these applications are submerged in the solution and the coolant, usually water, is passed through the element itself. The sections of the unit are cast of gray iron that is highly resistant to attack from both the solution and its fume.

GENERAL BOX COMPANY TO MAKE PALLETS

The General Box Company, Chicago, Illinois, has recently announced that they are now in production on shipping pallets and skids. The General Box pallet will be known to the trade as "Generalift."

Orders are now being taken and full-scale production is expected in the near future.

NEW DECI. POINT SLIDE RULE

Pickett & Eckel, 53 W. Jackson Blvd., Chicago 4, Illinois, has incorporated several new features into its Deci. Point Slide Rule.

Manufactured to determine the precise location of the decimal point with results up to 19 places, the rule is now being made of light-weight Dowmetal. Dowmetal can be machined to extremely close tolerances and will not be affected by heat, cold or moisture.

CATALOGUES RECEIVED

The Brown Instrument Company, Philadelphia, Pa., has recently announced the publication of a book, written by Donald P. Eckman, engineer of the company, entitled, "The Principles of Industrial Process Control."

The book contains technical and practical information about the science of automatic industrial control and covers such subjects as: Measuring means of industrial controllers, characteristics of measuring means, modes of automatic control, final control elements, process characteristics theory of automatic control, quality of automatic control, application of control engineering, automatic control systems, maintenance of exact control. The volume ends with a glossary of 126 terms and definitions. It also provides 119 references.

Wheelco Instruments Company, Chicago 7, Illinois, has released a new edition of its Thermocouple Data Book and Catalog.

Referred to as Bulletin S2-6, the 32 page catalogue gives information on selection of proper thermocouples and carries installation aids. Prices are listed, descriptions given and recommendations made on thermocouples, thermocouple wire, lead wire, heads, connectors, plug and socket assemblies, insulators and protecting tubes.

The U. S. Stoneware Company, Akron 9, Ohio, has recently issued a booklet, entitled, "Corrosion-Resistant Masonry Material and Construction Manual".

The booklet was prepared to provide helpful facts and suggestions with regard to materials and construction methods for tanks, towers, pumps, floors and other masonry construction.

The booklet is well illustrated and gives charts, diagrams and tables to amply illustrate the text.

Towmotor Corporation, 1226 East 152nd Street, Cleveland 10, Ohio, has recently compiled a Product Data File giving complete information about Towmotor equipment.

The file is divided into sections: one featuring the model lift truck; another, Towmotor design and construction; still another designed to show the way to greater effectiveness in operation of lift trucks.

Blaw-Knox Company, Pittsburgh, Pa., has published a booklet dealing with their functional spring hangers and vibration eliminators.

Designated Catalog 2026, the colorful booklet contains diagrams showing various pipe lines and how Blaw-Knox products can be applied.

Headings include The Scientific Approach to Power Piping Problems, Improving—Simplifying Complicated Piping Systems, Multiple Rolling Action Type Roller Units, Application to Meet Special Requirements, Instructions for Installation of Vibration Eliminators and closes with a Typical Piping Problem.

The General Metals Powder Company, 130 Elinor Ave., Akron, Ohio, has recently published a four-page folder describing various types of Gempco compressed metallic friction materials.

Various clutch and brake discs are illustrated with information as to size and application.

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CURRENT STATISTICAL POSITION OF GLASS . . .

(*Continued from page* 568)

1944. This indicates about 28 per cent under September and 19 per cent under October 1944. The first ten months of 1945 is reported to show a production of 83,616,121 sq. ft., as compared to 87,305,759 sq. ft. produced during the January-October 1944 period.

Due to a delay in the receipt of figures from one manufacturer, the totals shown for production, shipments and inventories, pertaining to automatic tumblers, and manufacturers' sales, pertaining to table, kitchen and household glassware, are necessarily only close approximations of the actual figures.

Automatic tumbler production for the month of October is estimated to be 6,082,442 dozens. September production was 5,394,230 dozens which is about 12 per cent less than for October. October 1944 was reported at 5,607,953 dozens representing about 8 per cent less than for October this year. Shipments for October were 6,147,979 dozens, as compared to 5,353,617 for September and 5,866,001 for October 1944. The October 1945 figure represents a rise of about 14 per cent and 4 per cent, respectively, over September 1945 and October 1944.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware were reported at 2,840,200 dozens for October. September reports showed a total of 2,583,014 which is close to 10 per cent less than October. However, October 1945 shows an approximate decrease of 16 per cent from the October 1944 figure of 3,386,484 dozens. Total sales for the January-October 1945 period are estimated to be 38,889,344 dozens.

AMERICAN WINDOW GLASS ANNOUNCES APPOINTMENTS

The American Window Glass Company has recently announced the election of Col. Thomas C. Davis as a Director of the company to fill the vacancy caused by the death of William Munro. The company made known the election of G. J. Graham as a Director, R. J. Whalen as Vice President and H. W. McIntosh as Assistant to the President.

Mr. Graham is president of Lummis-Graham Glass Company. Mr. Whalen has served for many years as secretary to the President and, in addition to his new position, acts as Secretary of American Window Glass Company. Mr. McIntosh has served as assistant manager of the furnace engineering division.

WYANDOTTE APPOINTS NEW MANAGER

The Michigan Alkali Division of Wyandotte Chemicals Corporation has recently announced five promotions which are to become effective January 1.

Carl Van Laaten continues as the company's special representative to the glass industry and will assist the Chicago, St. Louis and Cincinnati offices. Mel Thompson, former Detroit manager, transfers to Chicago.

Horace Brunner, of the sales staff, becomes manager of the Detroit office. M. J. Conway, formerly New York salesman, becomes manager of the newly opened Pittsburgh office of the Michigan Alkali Division and Pete Fuger, of the sales staff, moves to St. Louis as manager.

Dr. Estelle Glancy, American Optical Company research scientist, uses a spectrometer to demonstrate that light travels faster through beryllium fluoride glass than through any other glass, solid or liquid.

OPTICAL PROPERTIES OF BERYLLIUM FLUORIDE GLASS IS MEASURED

In a recent news release, the American Optical Company states that light travels faster through beryllium fluoride glass than through any other glass, solid or liquid, and that the optical properties of this glass have been successfully measured for the first time.

By way of comparison the report pointed out that light traveling through space reaches a rate of 186,000 miles per second and, through the beryllium fluoride glass, travels at 146,000 miles per second. Further comparisons offered are that light travels through water at the slower pace of 140,000 miles and through spectacle glass at 122,000 miles per second.

The measurements also showed that the glass separates light into its component colors far less than any previously known substance. Accordingly, if it could be used in making a lens it would produce less color aberrations.

Scientists of the optical company, in search of new types of glass with unusual optical properties to help lens designers improve cameras, microscope and other optical instruments, investigated the beryllium fluoride glass and finally succeeded in polishing and measuring it, an exceptionally difficult feat because the glass is highly unstable.

The work was accomplished by Dr. Estelle Glancy and Carl G. Silverberg under the direction of Dr. E. D. Tillyer. The glass is now undergoing further study.

The glass-forming properties of beryllium fluoride, used in making beryllium metal which in turn is employed to harden copper and other metals, were first predicted and demonstrated in 1927 by V. M. Goldschmidt, a German scientist. He predicted the glass would have a low refractive index and a low color dispersion, but apparently never measured these optical properties, stating only that the refractive index was lower than that of water.

Special steps had to be taken to measure the glass because it is extremely hygroscopic. When exposed to air, it absorbs moisture so rapidly that a prism made of it collapses into a puddle. As a result, such prisms could only be polished by means of techniques specially developed for the investigation.

In composition the beryllium fluoride differs from ordinary silica glass in that fluorine, replaces oxygen and beryllium replaces silicon. The samples measured were made by the Brush Beryllium Company.

HENRY F. CLARK OF AMERICAN WINDOW GLASS COMPANY DIES

Henry Fisher Clark, glass manufacturing consultant of the American Window Glass Company, died rather suddenly on November 18.

Mr. Clark was a graduate of Penn State College in mechanical engineering and became superintendent of the Wonham Magor Engineering Works. He later joined American Window Glass Company and held supervisory capacities since 1905.

Mr. Clark took American engineers to Europe and Asia to install the company's mechanical cylinder blowing process and, in 1915, was placed in charge of the company's experimental work. In 1921 he became superintendent of the Belle Vernon factory and then of the Arnold plant. He assumed the position of glass manufacturing consultant in June in which he was active at the time of his death.

• The Brooks Rotameter Company has recently been formed for the manufacture and application of rotameters. A factory with 18,000 square feet of floor space has been acquired at Lansdale, Pa., and manufacture has already been started.

TREASURER NAMED AT PENN SALT

Warner R. Over has recently been named Treasurer of the Pennsylvania Salt Manufacturing Company. Mr. Over replaces L. A. Smith, who served as Vice President and Treasurer, now retired.

Joining Pennsylvania Salt as a clerk in 1904, Mr. Over became Secretary of the company in 1940, combining this with the title of Assistant Treasurer. He will now act as Secretary-Treasurer.

• A meeting of the committees of the New York Section of the American Ceramic Society was held November 14. It was decided that annual dues would be $1.00. This rate will apply to non-members as well as regular members of the Society. A meeting of the full membership is planned for sometime in January.

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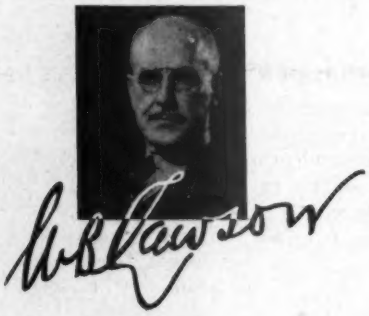


Merchants, Manufacturers' Sales Agents, Industrial Chemicals and Nonferrous Metals, Warehouse stocks in New York, Cleveland, St. Louis and Detroit.

Distributors for American Potash & Chemical Corp. (Borax and Boric Acid); Darling & Co. (Oleic and Stearic Acids); Duquesne Smelting Corp. (Nonferrous Metals, Zinc Dust); Ferro Drier & Chemical Co. (Driers and Metallic Soaps); Lindsay Light & Chemical Co.; Merck & Co. (Laboratory Reagent Chemicals); Philadelphia Quartz Co. (Silicates); Stauffer Chemical Co. (Sulphur); Tennessee Corp.; Virginia-Carolina Chemical Co.; Wyandotte Chemicals Corp.; and others.

NEW PROTECTIVE COATING FOR GLASS MOLDS

A new protective coating based on Vinylite resins is being furnished by the Cordo Chemical Corporation, Norwalk, Conn., for use as a covering for a variety of products, including glass molds.

The finish forms a continuous film of purposely low adhesion so that it may be stripped from the surface beneath without damaging it. It does not require baking or heat treatment for fusion, but can be applied by either the dip, spray or brush method.

This mold for casting glass forms, protected with coating based on Vinylite plastics, is clean and bright despite long storage; immediately usable when stripped.

The film protection is strong and durable and affords protection against weathering, corrosion, mechanical abrasion and scuffing. To remove the film, a small break is made in the surface and the coating is stripped off quickly and easily revealing the mold clean and bright despite storage. The mold is immediately usable when stripped. These new coatings can also be made in color as a means of identification by color-coding.

FIRE TESTS OF TEMPERED GLASS

Tempered or case-hardened plate glass is preferred to untempered glass in many locations on account of greater strength, and also to wired glass on the score of appearance. Although not intended for use in fire protectives for openings in the same manner as wired glass, the reaction of tempered glass to fire exposure is of interest from the standpoint of hazard from flying fragments.

Tests at the Bureau indicated that plain glass will begin to fracture as soon as the flame touches it, with jagged pieces falling out without scattering. Tempered glass cracks suddenly after a few minutes of fire exposure into small granular pieces without sharp edges that are projected to considerable distances. In the case of wired glass, although it cracks, no pieces are dislodged and it remains as a fire barrier for 30 minutes or more of fire exposure until it melts, softens or sags under its own weight.

HARTFORD-EMPIRE REIMBURSES CONTAINER MANUFACTURERS

Final settlement of the payment of a portion of the impounded funds held by the Receiver for the Hartford-Empire Company to that company's licensees was approved by Federal Judge Frank L. Kloeb in Toledo on November 20. The total amount returned to the glass manufacturers, numbering somewhere between fifty-five and sixty concerns, amounted to $12,744,683.78. It is understood that this payment is in consideration of the waiving by the various companies of all claims against Hartford.

Still in the process of negotiations between Hartford-Empire and the glass manufacturers is the matter of charges for field and laboratory services.

No agreement has as yet been reached in the matter of "use royalties" which phase of the situation deals with the manufacture of machinery by manufacturers other than Hartford which equipment would involve the use of Hartford patents. It was reported that the Court has granted a ten-day extension of time for hearing from the original deadline of November 30.

STAFF CHANGES AT UNIVERSITY OF ILLINOIS

Staff changes at the University of Illinois were made known when the appointments to new posts of W. D. Fitzpatrick and A. W. Allen were announced.

Mr. Fitzpatrick has been made an assistant to give instruction in the Department of Ceramic Engineering. He has recently been released from the Navy.

Mr. Allen has been appointed Special Research Associate in the Department of Ceramic Engineering on a special project for the development and application of ceramics in the aircraft field. Mr. Allen was formerly with the Harbison-Walker Refractories Company, after which he joined the Air Corps.

BALL BROTHERS EXPANDS

A recent announcement has made known the purchase of a thirty-acre tract of land at El Monte, California, by the Ball Brothers Company of Muncie, Indiana.

Plans are underway for the erection of a plant to be used in the manufacture of glass containers and closures. The particular tract was purchased because of its strategic location for procurement of raw material and distribution of the finished products. It is adjacent to the tracks of the Southern Pacific Railway.

The West Coast representative of the company is Hugh Crawford who is located in El Monte.

PACKAGING EXPOSITION DATES ANNOUNCED

It has recently been announced that the Packaging Exposition of 1946 will be held in the Public Auditorium, Atlantic City, N. J., from April 2 through April 5, 1946.

The show is being sponsored by the American Management Association and will be the largest in the fifteen year history of the exposition. It is expected that 150 leading manufacturers of equipment, machinery, supplies and services essential to the field of packaging, packing and shipping will participate.

ALFRED INAUGURATES NEW PRESIDENT

Gov. Thomas E. Dewey was the principal speaker at the inauguration of J. Edward Walters as the eighth president of Alfred University on November sixteenth. The governor stressed the importance of the glass and ceramic industries of the state, and the educational and research work of the N. Y. State College of Ceramics, of which also Dr. Walters now becomes president.

Blackstone Studios

President Walters graduated in mechanical engineering from Purdue University, following service as an officer in the A.E.F. in World War I. He holds the degrees of M.S. in M.E. from Purdue, 1928, and Ph.D. in personnel administration from Cornell, 1934.

In student counselling and personnel work, and in industrial personnel and labor relations, Dr. Walters has had an active and useful career; at Purdue until 1940, and as an industrial consultant and management officer, since 1928. He is the author of several books and numerous magazine articles on personnel methods and problems.

At the inaugural, Gov. Dewey was presented for the LL.D. degree by Dr. J. Hillis Miller, of the State Education department. Among the representatives of sister institutions was Dr. John C. Hostetter, President, Mississippi Glass Co., as a graduate of Bucknell and a member of the Board of Managers of the College of Ceramics. Another member of the Board in attendance was C. Forrest Tefft, Alfred alumnus, president of the American Ceramic Society.

PITTSBURGH SECTION DECEMBER MEETING

The Pittsburgh Section of the American Ceramic Society has scheduled its December meeting for the evening of December 4.

The evening's program includes a talk by Woldemar Weyl, Director of Glass Science, Inc., who will discuss "Adhesion to Glass." Herbert Insley, head of the Department of Earth Sciences, will speak on "The Solubility and the Rate of Solution of Refractories in Molten Glass."

The meeting will be held at Mellon Institute and election of officers for the 1946 season is included in the business of the evening.

ACHESON APPOINTS WESTERN SALES AGENT

Acheson Colloids Corporation has recently announced the appointment of Pennant Oil & Grease Company as far-western sales agent. The Pennant staff will service California, Oregon and Washington state.

The new activity will be headed by C. L. Haserot, president of Pennant Oil & Grease Company and who has specialized in the Department of Chemical Engineering at California Institute of Technology.

(*Continued from page* 560)

not extend the same "residual valences" to the lead atoms. Its more rigid structure does not permit the electronic interpenetration which is necessary to bring lead atoms into solution. An addition of 40 Mol % KCl decreases the solubility to one five hundredths of its original value.

Composition of the Melt		*Solubility of Metallic Lead*
Mol $PbCl_2$	*Mol KCl*	*x 10,000*
100	0	3.7
90	10	2.27
80	20	1.51
70	30	0.64
60	40	0.006

In our monograph on Colored Glass we coined the term "metallophilic" for designating the property of an ion or molecular group to exert attraction forces toward metals. Even if the forces emanating from these metallophilic groups are not yet completely understood, their concept provides us with an analogue to similar phenomena in aqueous solutions. The solubility of benzoic acid in water for example is very low. The hydration forces are not strong enough to overcome the intermolecular attraction which is holding the benzoic acid molecules together in the crystal lattice. Addition of the more soluble sodium salt of the benzol sulphonic acid to water provides an increase in solvation. The solubility of benzoic acid is raised because of the dispersion forces acting between the two benzene rings, the one of the dissolved benzol sulphonate and the one of the benzoic acid. Substances which increase the solubility of another substance in water have been called "hydro-tropic."[6]

The same phenomenon exists for metals in ammonia. Liquid ammonia is not a strong enough solvent to overcome the lattice energy of metallic lead, however, it does dissolve alkali metals. If an alkali metal is added to the liquid ammonia, lead can be brought into solution.[5a] The weak forces acting between ammonia and lead are now replaced by the strong forces ammonia-alkali metal-lead metal. Lead forms intermetallic compounds with alkali metals called alkali polyplumbides.

Now let us go one step further. Instead of ammonia we consider a soda-lime-glass. Its solvent forces are not strong enough to overcome the forces which hold the gold in the metallic phase. Gold is soluble only at the highest temperatures where its vapor pressure reaches noticeable values. Platinum with its much lower vapor pressure is practically insoluble. On cooling the glass melt, the gold precipitates in globules and relatively large crystals. The addition of 0.5-2.0% tin oxide changes the solubility curve completely. Tin ions have the same effect on the system gold-glass as the alkali metal has on the system lead-ammonia or the benzol sulphonate on the system benzoic acid-water. The tin ions increase the low temperature solubility of noble metals in glasses.

The change in the solubility curve makes ruby formation possible. The same is true for the systems glass-metallic copper and glass-metallic silver. These examples show that tin ions in a silicate melt exert strong metallophilic properties which enhance solubility. The next step in our approach would be to investigate how far we are entitled to the conclusion that the same effect will be observed for the adhesion of metals to the glass surface. Solvent forces and adhesion forces are principally identical. We know, however, that the structure of the surface of a glass cannot be identified with that of its interior. In order to decrease the free surface energy an atomic rearrangement takes place which brings those ions to the surface which are most easily satisfied with incomplete coordination. As a result we find alkali ions driven to the surface. Incomplete SiO_4 tetrahedra which would extend strong valence forces react with the moisture of the atmosphere and form SiOH groups. If we treat a glass surface with a solution of a tin salt, we can be fairly sure that it covers itself with tin ions. Such treatment is generally known to increase the precipitation rate of silver during mirroring. It seems to be less known, however, that the same treatment has an even greater effect on the adhesion of the metal film once it has formed.

O. Machia[7] studied the mirror formation on various materials such as glass, celluloid and gallalite. With the untreated material, silvering began after 100-200 seconds. Previous treatment with tin compounds caused the first mirror to form after 12-30 seconds.

Machia also determined the relative adhesion by measuring the force necessary to rub off the metal from its support by means of a piece of leather. Stannous chloride treatment increased the adhesion 100 to 1000 times.

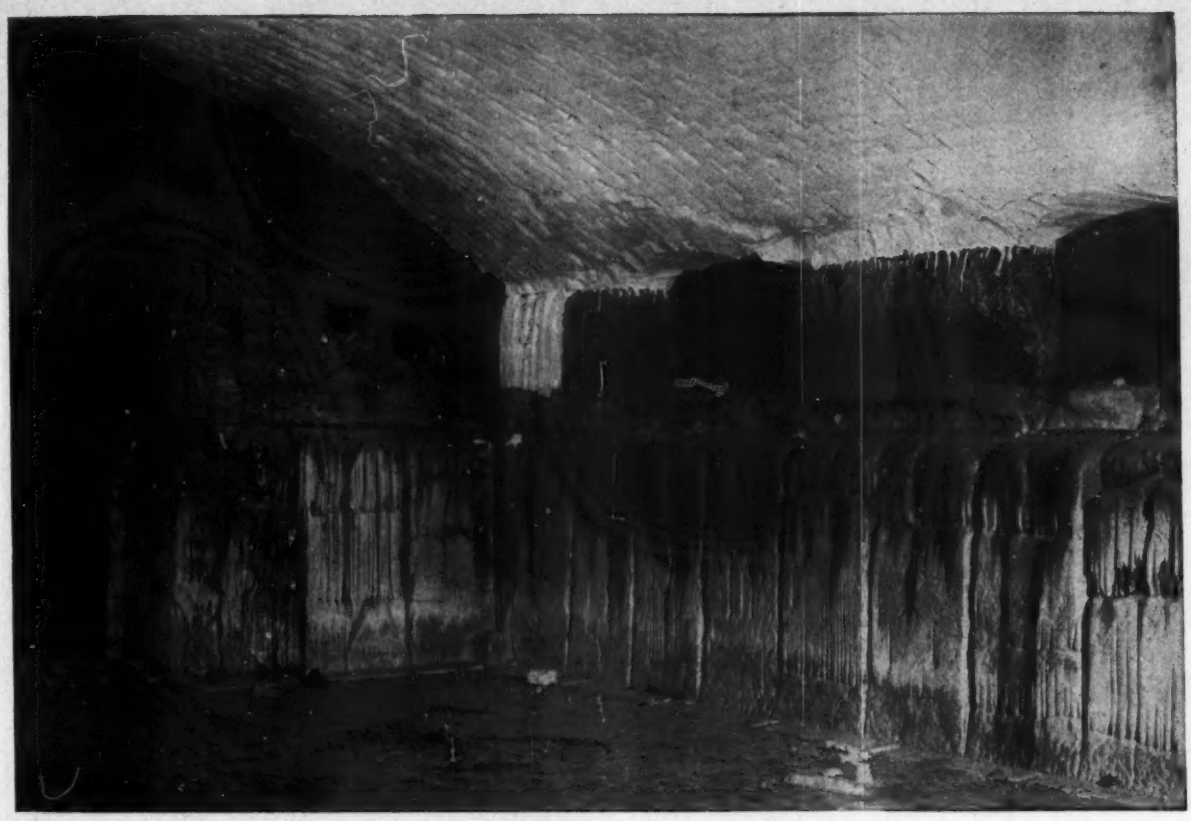
The Structure of the Glass Surface

The atomic structure of glasses of simple composition such as soda-lime-silicates is rather well understood. Glasses of this type represent an ionic network extending in three dimensions and having Si-O-Si bonds as the strongest linkage. If a piece of glass is broken, these linkages are broken and free valence forces extend into space until thermal motion enables the ions to rearrange themselves. At room temperature such a rearrangement would require a long time, but at elevated temperatures the surface undergoes a considerable change. The ions which are most easily satisfied with incomplete coordination, such as the alkalies and boron, assume positions at the surface and thus decrease its free energy.

At room temperature the same is accomplished by absorption of water vapor or gases. It is impossible to preserve the original "clean" surface even under experimental conditions, because even in the best obtainable vacuum there are still billions of molecules impinging each second upon each square millimeter of the surface.

The difference existing between a fresh and an aged glass surface can be easily demonstrated by breathing against the freshly broken surface of a glass, preferably a high refractive index barium glass. The moisture condenses to form a film which shows various interference colors. Light is reflected at both interfaces, air-water and water-glass, and the reflected waves interfere. After some time the glass fails to show this phenomenon. The chemical reaction with the water pro-

(*Continued on page* 576)



ANOTHER "THREE-YEAR" CORHART* ELECTROCAST TANK

A LITTLE over three years ago we published the story and operating data for a Corhart* flint-glass tank that had just finished a run of practically three years.

Today we are glad to report the results of that tank's successor—another "three-year" campaign just recently ended in which the melting and refining-end sidewalls, throat, doghouse and complete refining bottom of this unit were constructed with Corhart* Electrocast materials.

TOTAL DAYS	1,042
OPERATING DAYS	849
IDLE DAYS	193
MELTING AREA (SQ. FT.)	993
TOTAL TONS GLASS	141,029
CULLET RATIO	64.1%
TONS GLASS PER OPERATING DAY	166.1
TONS GLASS PER TOTAL DAYS	135.3
SQ. FT. PER TON PER TOTAL DAYS	7.3
SQ. FT. PER TON PER OPERATING DAY	6.0
TONS PER SQ. FT. PER LIFE	142

As we have said many times in the past, good production records are the result of good operation plus good refractories. Corhart* is glad to have had the opportunity of playing a part in this excellent performance.

*Not a product, but a registered trade-mark.

QUALITY ENDURANCE SERVICE

CORHART ELECTROCAST REFRACTORIES

(*Continued from page* 574)

duces a surface layer of hydrogen glass whose refractive index changes gradually from the low value of the liquid film to the high value of the bulk glass. The disappearance of the interface film-glass eliminates the second reflection and with it the light interference.

The diffusion of "water" into the glass is the result of a number of place exchanges between Na^+ and H^+ ions and constitutes, therefore, a time consuming process. For some purposes the layer of hydrogen glass might not interfere seriously with adhesion. For continuing the original glass structure by means of other building units such as coating the glass with fluorides, a deep layer of hydrogen glass is undesirable because it gives rise to gas evolution and decreases adhesion.

If the glass surface suffers major constitutional changes by merely being exposed to air, one can readily understand that polishing, rinsing with stannous chloride or exposure to silver containing solutions must bring about changes which leave little similarity between the structure and properties of the surface and those of the bulk of the glass.

We have learned that the presence of non-noble gas ions in the surface is a condition for the adhesion of most metal films. E. C. Marboe and the author[8] showed that in the chemical deposition of metals on glass, as in silver mirroring, the base exchange between Na^+ and a monovalent ion with non-noble gas character (Cu^+ or Ag^+) constitutes the first step. These ions firmly anchored in the glass structure provide the metallophilic groups which are essential for good adhesion. The same effect can be obtained by rinsing the clean glass surface with solutions of stannous chloride.

Sealing a metal to a glass at high temperature involves a similar phenomenon. Some metal oxides dissolve in the fused glass and the polarizable ions such as Cu^+ help to bridge the gap between glass and metal. The beneficial effect of sulphide ions on adhesion is based on the large size of the S^{--} ion and its high polarizability.

Considering these facts, one must realize that the atomic structure and with it the properties of the surface layer in contact with a mirror metal, a plastic or an anti-reflection coating can be very different from those of the interior of the glass. This now raises the question: "Which methods are available for studying the adhesion forces emanating from a glass surface?"

Methods for Stuying Adhesion Forces

The solubility of metals in glass melts as revealed by their precipitation (ruby formation) on cooling provides us with valuable information concerning the forces acting between glasses and metals at high temperatures and the temperature coefficient of these forces. Little or nothing, however, is revealed about the forces between glass and metal acting at room temperature.

If we join two solid media like a metal and a glass and then pull them apart, three possibilities exist. Fracture may occur either at the interface or in the metal or in the glass. The attraction between the molecules decides where rupture occurs. One usually takes it for granted that two metal plates, polished and plane, when covered with an oil film and pressed together will rupture at the metal-oil interface on pulling. However, this is not necessarily true. An oil film having the dimensions of a molecule cannot be considered a liquid. Some oils exert forces upon metals which are comparable with or even greater than the cohesion forces acting in the metal itself. In this case metal parts are torn loose if the plates are pulled apart rapidly.

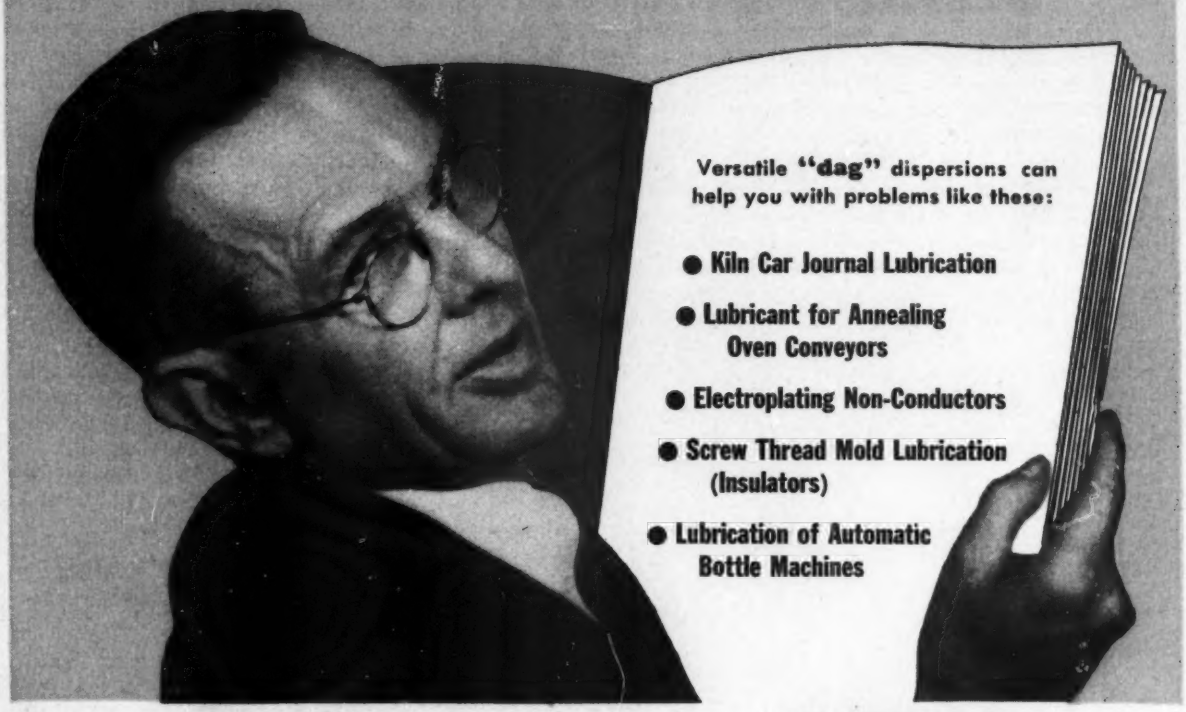
If glue is brought in contact with glass, it adheres and the adhesion forces are so strong that on drying its contraction tears conchoidal pieces out of the glass. This phenomenon has been used to produce decorative effects.

Another corresponding phenomenon showing that the adhesion forces between two media can be stronger than the cohesion forces in one phase has been observed when certain metals were pressed onto a glass surface. Zirconium is available in a ductile form which can be used like a pencil for writing on glass where it produces silvery lines.[9] This process differs principally from writing with a pencil on paper. In the latter case the lines are produced by mechanical abrasion of the graphite through the rough paper. Zirconium has a great chemical affinity for oxygen. Its valuable corrosion resistance is due to the inertness of its oxide, ZrO_2, and to the strong adhesion of the oxide to the metal. In writing one presses the zirconium metal against the glass surface. Si-OH groups, or maybe even broken Si-O-Si bonds, combine with the metal and produce a bond of the type glass-Si-O-Zr-Zr metal. The metal yields under tension and due to its ductility, a film of zirconium deposits on the glass surface. Here again the bonds between glass and metal were stronger than those forces which held the metal atoms together.

Other metals, such as soft iron,[10] produce a similar effect, but the quantity of the metal deposited is not sufficient to produce a visible mark. By means of a process which in photography is called "physical development" the metal particles can be used as nuclei for the deposition of other metals such as silver or copper and thus be developed to a size which makes them visible.

E. C. Marboe, M. Kist, and A. Mulvehill have developed in our laboratory a method for studying the forces between metal atoms on the surfaces of ionic crystals and glasses. This method is based upon the aggregation of noble metal atoms which can be easily followed by the change in light absorption and fluorescence. The first step consists of the adsorption of gold or silver ions on the surface to be studied. The second step, either thermal dissociation or reduction by hydrogen gas, changes the ions into neutral atoms. The atomic subdivision of both metals is colorless but in the case of silver may produce a white fluorescence on exposure to U.V. radiation. The atomic subdivision of a metal is not stable. The atoms try to aggregate and to form stable crystals. This is accomplished by surface diffusion and collisions. Surface diffusion is delayed by strong forces acting between the atoms and the surface of the carrier. The stronger the forces, the higher will be the temperature required to bring about aggregation of the metal atoms. The final step in this process consists of heating the substance covered with metal atoms for a certain length of time to various temperatures. The progress of the aggregation can be followed by means of the colors produced. Gold crystals of colloidal size appear pink. On further growth they change to purple

HAVE YOU A TOUGH PROBLEM?



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and finally if the crystals are large in size but small in number the color begins to fade. Silver atoms lose their fluorescence and develop yellow to brown silver crystals.

This work which is still in its initial stage already has given us some interesting information concerning the forces acting between metal atoms and glasses or ionic crystals. If the carrier substance is built of noble gas ions only, such as NaCl, MgO and BaO, the pink color of colloidal gold appears at about 250° C. and fades at 700-800° C. Crystals containing highly polarizable units such as rutile exert strong forces upon the gold atoms which prevent their aggregation up to 800° C. By comparing one oxide in various modifications, one obtains an indication of the polarization forces as a function of the crystal structure. Comparisons between the oxide and some of its compounds reveal the influence of atomic structure, coordination number and environment. Some titanates for example behave very much like TiO_2. Sodium-titanium-silicates, on the other hand, show much weaker forces.

The connection which exists between polarizability and adhesion forces on one hand and polarizability and dielectric properties on the other may widen the scope of our new method and make it a useful tool in ceramics, especially in the field of ceramic bodies of high dielectric constants.

For exploring the adhesion forces between glasses and non metallic media other methods have to be used. One possibility is to study the replacement of one molecular species by another using the static friction as an indicator. The origin of some of the best work on adhesion and on spreading of fluids on glass surfaces can be traced to some thoughts which Lord Rayleigh had on the slipping of a cup of tea about its saucer. Probably everybody noticed that slipping can be prevented if the parts in contact are wetted with a drop of tea. This paradoxical behavior of the porcelain, that lubricating the solid phases by wetting with water increased friction, led to a thorough examination of friction between glass surfaces. W. B. Hardy and J. K. Hardy[11] measured the force required to move a loaded watch glass over a polished glass surface. No matter whether they used optically polished glass or plate glass, the force was relatively great if the surfaces were thoroughly cleaned. The clean surfaces could not slide over one another. Under the slightest pressure they seize and grow together. Pulling the watch glass over the surface produces a sequence of fractures as can be seen under a high power microscope. The track of the loaded watch glass is about 50 μ wide and consists of fractured glass. A molecular film of oil prevents seizing and decreases friction. Water is not as effective but it adheres stronger to a clean glass surface. Based on these experiments, a simple explanation could be given for the teacup experiment. The sliding is caused by a film of grease which adheres to the surface of cup and saucer. Wetting with water replaces the lubricant and friction increases.

A watch glass moved over a glass surface can also be used to study the speed with which a monomolecular layer of a liquid spreads over the glass surface. If the glass plate is touched by a drop of acetic acid for example, the drop does not spread out, but a molecular layer of acetic acid will cover the glass practically instantaneously.[12] Similar phenomena have been studied in respect to organic compounds spreading on water. On glass the film of molecular thickness is invisible but can be detected by means of its lubricating qualities.

Experiments of this type with different substances spreading on glass surfaces which had undergone various treatments might contribute materially to our better understanding of adhesion to glass at room temperature.

The competition between the natural oil film on a glass surface and water condensed from the vapor phase finds an application in the breath figures used for invisible marks on glass. A glass surface, for example that of a finished lens, is exposed to a chemical which alters the structure of the glass to a depth much less than the wavelength of light. For this purpose various materials, such as phosphates, tin or silver compounds, are brought on the glass by means of a rubber stamp and baked slightly. These marks are invisible but show up clearly when one breathes against the glass. The reason is that the changed and the unchanged glass surfaces exert different adhesion forces on the oil and the water film. As a result the water condenses in lenses of different contact angles and different shapes. The shape of the droplets in turn influences the nature of the diffused light reflection.

Summary and literature on adhesion

Despite the manifold interests in operations where glasses are joined with other materials, very little information is available on the principles involved. In order to guide workers interested in this field, the fundamentals concerning the forces acting between different molecules are mentioned briefly and borderline fields are described from which valuable information can be drawn. For the convenience of our discussion, the joining operations were classified as follows:

1.) The medium to be joined is compatible with the glass, that means its structure consists of ions which are either oriented (ionic crystals) or randomly arranged (glasses). In this case adhesion is due to the same forces acting in both media. We deal with a continuation of the glass structure by means of other building units. Example: Sealing two glasses together; casing two glasses; glazing ceramic materials; coating glasses with oxides: Luster-colors, TiO_2, SnO_2; coating glasses with fluorides: Anti-reflection film, MgF_2.

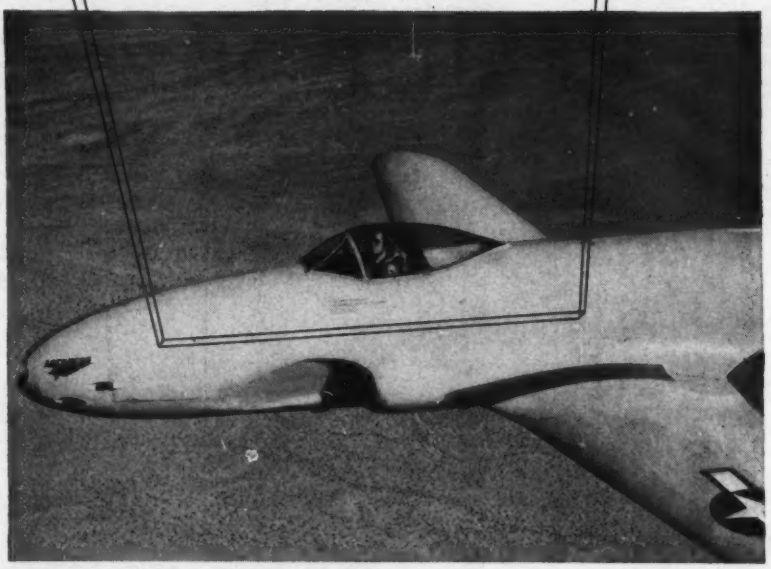
2.) The medium to be joined is incompatible with the glass but has the possibility of entering into a chemical reaction with the glass surface, which for all practical purposes can be considered a hydrogen glass. Example: Adhesion of glue or gelatine; adhesion of glycerol-litharge cement; adhesion of "Dri-film": Organo-Silicon chlorides.

3.) The medium to be joined is incompatible with the glass and has no possibility of entering into a chemical reaction with the glass surface, but adhesion is due to the formation of an intermediate layer. a) Formation of an oxide film on metals. Example: Chromium oxide is responsible for adhesion of Ni-Fe-Cr alloys to glass. b) Formation of a glass surface containing highly polarizable ions such as S^{2-}, Co^{2+}, Ni^{2+}, Ag^{+}, Cu^{+}. Ex-

(*Continued on page* 580)

Shooting Stars Need Glass that can travel 500 miles per hour

LOOK TO THE FUTURE *thru Glass!*



The future of aviation will call for high speed flying. And high speed flying calls for extra-clear vision for the pilot. Glass has already proved its worthiness.

When Lockheed built the P-80, the Shooting Star, powered by jet propulsion, a glass nose was developed that could stand the pressure of over 500 m.p.h. . . . 115 pounds of pressure per square inch . . . and still give crystal-clear vision. Glass to withstand such heavy pressure must be *good* glass.

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Granular Hydrated Potassium Carbonate 83-85% K_2CO_3

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Since the flow of gases from one zone to another is caused by the differences of pressure in the various zones, it is apparent that the control of pressure has a pronounced effect on the distribution of gases and therefore, temperature within the kiln.

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MICHIGAN CITY, INDIANA, U.S.A.

ADHESION TO GLASS . . .

(*Continued from page* 578)

ample: $SnCl_2$ treatment of glass before mirroring; Cu^+ entering glass surface in copper to glass seals and "mudding" before gilding.

4.) The medium to be joined is incompatible with the glass, and there is no possibility for a chemical reaction or for the formation of an intermediate layer. In this case adhesion is due to the dispersion or van der Waal's forces. Good adhesion requires the presence of large molecules. Example: Adhesion of high polymers to glass: Safety glass.

This classification can be very helpful if used wisely. It must be realized that it is arbitrary because there is no sharp distinction between polarization forces and chemical bonds. It also neglects the adhesion which is produced by the mechanical grip. The latter doubtlessly plays an important role in the adhesion of glazes to ceramic bodies, where crystals growing from the body into the glaze provide strong adhesion. The same is probably true for certain enamels or ground coats.

Another weakness of this classification is the fact that probably most practical cases would belong into two or maybe more groups. Plastics adhere by means of dispersion forces and by polar groups which might enter into a chemical reaction with the glass surface. A copper to glass seal can be based on the formation of a Cu_2O layer and on the Cu^+ ions entering the glass. Probably both processes take place and the working conditions (temperature, duration, atmosphere) decide which of the two dominates.

The chief purpose of this subdivision is not to recommend a sharp classification but to call attention to borderline fields from which further information can be drawn. No attempt has been made to give a survey of the literature but the references are selected from the viewpoint of fields which are worthwhile studying.

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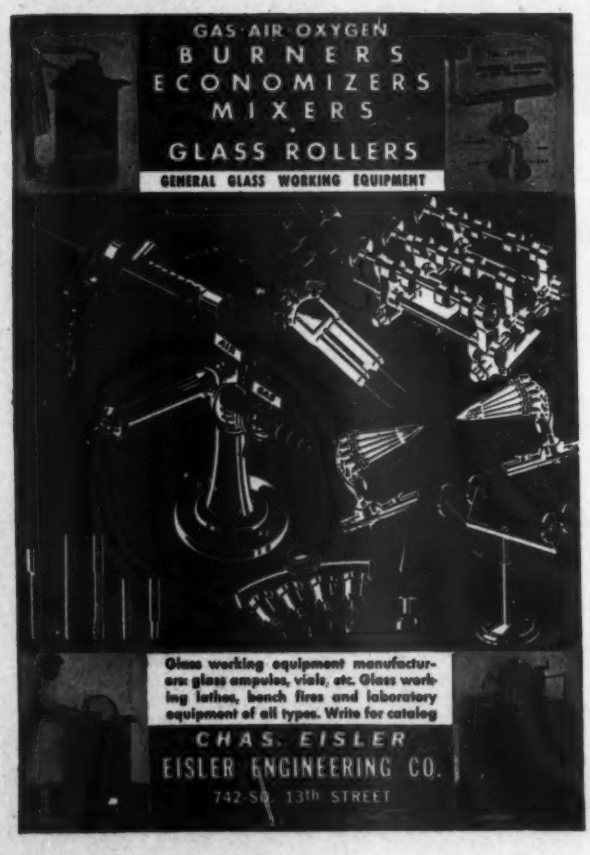
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INVENTIONS AND INVENTORS . . .

(*Continued from page* 566)

Miscellaneous Processes

Two patents have been assigned to the Libby-Owens Glass Company by Gerald White in one case and White and Grimes in the other.

The White patent No. 2,388,808 shows the tempering of sheet glass, in which the glass is first heated and then cooled by an air blast in which the air is first conditioned by the removal of moisture to bring it to a pre-determined humidity and also to bring the air to a pre-determined temperature.

The patent to White and Grimes, No. 2,388,809, also relates to tempering sheet glass and it is aimed particularly to supporting the glass so that it will not sag or warp or be marred by the supporting means. This is accomplished by a novel construction and arrangement of the glass supporting means. This device is said to be particularly adapted for use in supporting curved sheets of glass.

Sheet and Plate Glass

Patent No. 2,387,886 has been granted to Manson L. Devol who assigned it to the Pittsburgh Plate Glass Company. The object of this invention is to produce a rolled sheet of glass which is more uniform in thickness, has a better surface, and on which the wear upon the rolls is reduced. This is accomplished by providing a pair of rollers at least one of which is driven fast enough to retain a thin film of air between the roll and the glass.

As shown in Fig. 6, a tank 10, of the usual design, is provided at forehearth 11 having a discharge opening through which the glass flows to be rolled. Draw lips 14 and 16 permit the sheet of glass to flow out between them. The upper lip 14 is adjustable to regulate the thickness of the glass. These lips are shown as provided with chambers 19 and 20 which contain gas under slight pressure. The portion of the lips engaging the glass are of porous material such, for instance, as granular silica. This permits the passage of a slight amount of gas which prevents direct contact between the lips and the surface of the glass. After leaving the lips, the glass passes between rollers 34 and 35 which are hollow to permit the circulation of a cooling fluid. The upper roller is capable of adjustment to regulate the thickness of the glass. Both of the rollers may be rotated at high speed to entrain adherent films of air upon their surfaces. If desired, only the upper roller may be rotated at high speed, while the lower one may be rotated at the same speed as the glass. The speed of the upper roller may be varied but a peripheral speed of 800 to 6,000 inches per minute is recommended. The upper roller may be driven either forward or backward without any substantial effect upon the glass. After leaving the rollers, the glass is cooled by the chambers 42 and 43 containing cold air. The glass engaging sides 47 and 48 of the chambers are of porous material which may be the same as used for the drawing lips 23. The glass is carried away to the lehr by a driven roller 51 and supporting rollers 49. The pull exerted by the roller 51 should not be sufficient to stretch the glass too much.

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Herbert D. Rollo has recently been appointed New England District Sales Manager of the Wickwire Spencer Steel Division, Colorado Fuel and Iron Corporation.

Mr. Rollo joined Wickwire Spencer in 1933 and had previously been associated with the American Chain and Cable Company.

In his new position, Mr. Rollo will have full charge of all sales operations throughout New England as part of an expansion program by Wickwire Spencer in developing new and wider postwar markets throughout the New England area.

WESTINGHOUSE DEVELOPS "BLACK LIGHT" LAMP

The development of a fluorescent lamp producing unseen ultraviolet rays has been announced by Westinghouse Lamp Division, Bloomfield, New Jersey.

The invisible ultraviolet rays generated by the new lamp activate the multi-colored fluorescent pigments on dials and control knobs. The tubular lamp is a simplified version of the fluorescent tube used for lighting purposes, but in place of the phosphors selected for the production of this type, the new lamp has special black light phosphors coating the inner surface. It will be used with a special glass mask which blocks out stray visible light present.

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In a recent announcement of the Columbia Chemical Division of the Pittsburgh Plate Glass Company, it was revealed that Harry W. Gleichert has been appointed director of sales for the Division.

Mr. Gleichert has been associated with the company since 1920 and has been employed in the laboratory, development department, plant operation, technical service and in the sales department. He was made assistant director of sales in 1937.

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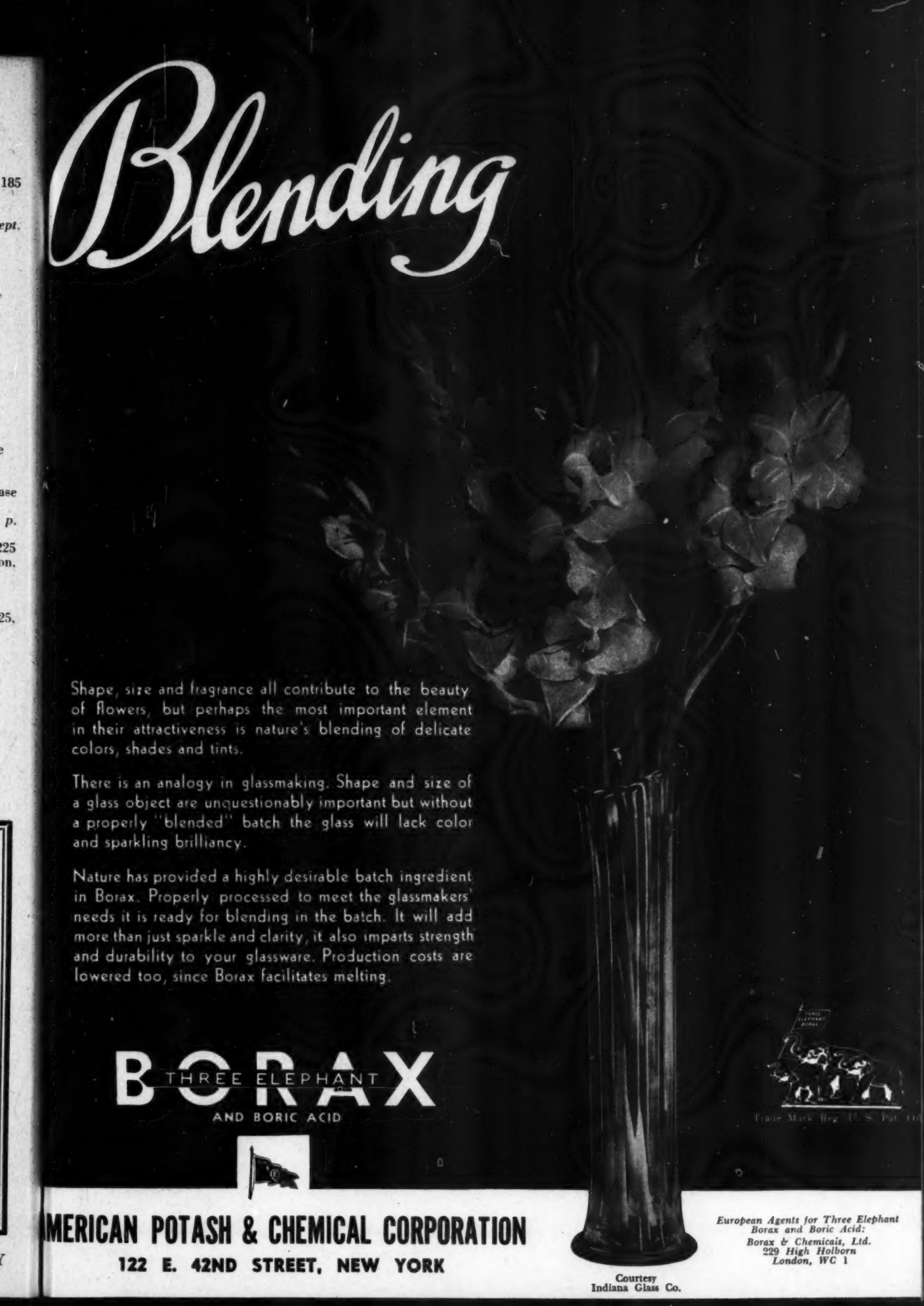

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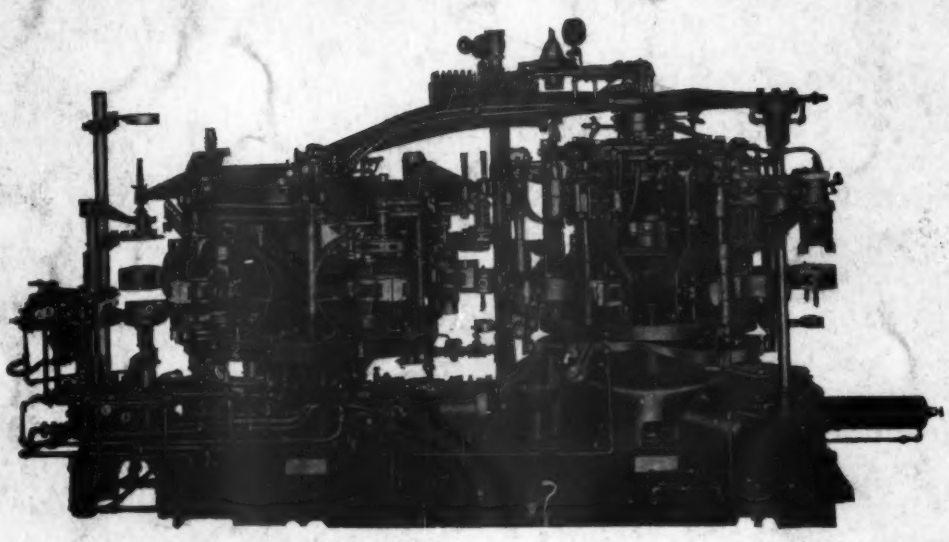

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